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SVIC NOTES

As you read these notes, the 50th Shock and Vibration Symposium will be a part of history. Since I am writing before the fact, I feel free to make a few predictions. First and foremost, if you missed this meeting, you will have missed an outstanding one.

This Symposium was planned as a special celebration of 50 meetings held over a 32 year period. The objective was to look at our technical area in perspective. We were to have examined the dynamics field in retrospect, to relate current capabilities to progress and to take a look at future technological thrusts. I predict that we will have accomplished this objective, at least in a broad sense.

I predict that the keynote speakers will have laid down some challenges that will be taken up during the coming years. Prior to the Symposium these distinguished speakers: Lieutenant General Robert J. Baer, Deputy Commander, DARCOM; Dr. T.G. Horwath, Director of Navy Technology; and Brigadier General Brien D. Ward, Director of Science and Technology, AFSC, have all shown an appreciation of the importance of our technology and a keen desire that our accomplishments enhance the DoD mission. We will have been inspired in the measurement area by Dr. Robert M. Mains, who through years of experience has developed an insight that is valuable to our technical community. We will have heard an informed view on analysis and design from Mr. Robert Hager, a man who has moved up the ranks from the engineering bench to the highest level of management in an aerospace corporation. We will have heard about materials, their dynamic characteristics, and their importance in design from Messrs. Richard Shea and John Mescall of the Army's AMMRC. Dr. Allen Curtis, with well-deserved recognition in our field, will likely have told us about some unresolved problems in the test area.

We will also have heard our field discussed from the viewpoint of researchers outside the U.S., including Australia, the United Kingdom, Sweden, and West Germany. The increasing international flavor of our symposia can only serve to enhance our progress. In general, I predict that the 50th Symposium will come to be regarded as one of the best. If you were unable to attend, I suggest that you might like to order the Bulletin when it becomes available.

Finally, I want to take this opportunity to publicly commend Mrs. Barbara Szymanski for her outstanding service to SVIC and the technical community over the last several years. Barbara is an extremely talented person and, because of these talents, is leaving SVIC in order to advance her career. We at SVIC will miss her very much, but offer sincere wishes for continued success in her future endeavors.

H.C.P.

EDITORS RATTLE SPACE

INGENUITY -- THE FUTURE WITH ENGINEERING

I recently read an interesting article titled "Why Can't We Have it Both Ways?" by Mr. John W. Hanley*, Chairman and President of Monsanto Co., regarding the role of human ingenuity in attaining economic progress without sacrificing the quality of life -- a combination thought by many to be impossible. According to Hanley history has shown that human ingenuity has allowed us to "have it both ways" in the past and that it can continue to do so. He cites the better use of materials: a 200-ton jetliner carries more passengers annually than the 85,000 ton Queen Elizabeth; the environment is cleaner despite increased automobile traffic. Mr. Hanley's article was a breath of fresh air in a sea of negative thinking.

The engineering community has always contributed to advanced technology through innovation. I believe many of the apparently insurmountable problems of today -- energy, pollution, shortage of raw materials -- will be solved if engineers are given the chance -- and the time and money. But some government priorities will have to change. And some popular short-term programs will have to be replaced by longer term programs whose effects will be longer lasting.

In the past engineering ingenuity has brought us advances in electronics unheard of 25 years ago. With these advances the computer has become an everyday tool. Advances in the use of materials have brought more efficient automobiles and structures. There is no reason to believe that ingenuity cannot result in spectacular advances in the energy field. It has taken our current economic dilemma to motivate the exploration of such alternative energy sources as solar energy and to increase efforts on solving the problem of usable nuclear energy.

It is up to society to motivate these efforts. The question of safety can be raised -- and made part of the criteria for design and operation of new facilities. However, safety should not be used as an excuse or reason for not utilizing technology. The demands on the engineering community for increased technology can be satisfied provided society remains motivated -- even if additional constraints are placed on technological utilization.

R.L.E.

*Business Week, September 10, 1979.

DYNAMIC MECHANICAL PROPERTIES OF FIBER-REINFORCED COMPOSITE MATERIALS

R.F. Gibson* and D.G. Wilson**

Abstract *- This paper reviews recent efforts to characterize the internal damping and dynamic stiffness of fiber-reinforced composite materials under vibratory loading. Several trends are noted, and suggestions are offered regarding directions of future research.*

Since the publication of the first article in this series [1], the study of dynamic behavior of fiber-reinforced composites has been directly affected by several key developments. The effects of some of these developments are just beginning to show up in the literature. Indeed, some of the recent advances in experimental techniques and instrumentation appear to be ready for application by composite material researchers.

The availability of digital fast Fourier transform (FFT) processors is revolutionizing the field of vibration analysis. As a result, applications of FFT-based techniques are flooding the literature. The same could be said regarding the impact of finite element techniques on analysis of composite materials and structures. Increased concern about the effects of environmental conditions (i.e., temperature and moisture) on mechanical properties of fiber-reinforced plastics has prompted the development of various environmental testing techniques. Motivated by weight savings and resulting increases in gasoline mileage, the automotive industry is projecting high-volume use of fiber-reinforced composites. Resulting concern about producibility and reliability has led to the evolution of new classes of composites which must be characterized. The sensitivity of dynamic mechanical properties to microstructural damage and defects is the basis for several new nondestructive testing techniques.

This article surveys recent publications in the areas just mentioned. The emphasis is on vibrations rather than wave propagation, and on measurement rather than theory.

ANALYSIS

The basis of composite materials micromechanics is still the elastostatic analysis, which was discussed in the first article [1]. The effective moduli derived from the elastostatic analysis can generally be used for most vibration frequencies encountered in engineering, but not for high frequency wave propagation. Scott [2] has surveyed recent work on linear elastic wave propagation in anisotropic media. Attempts to compare predicted dynamic properties with measurements often involve beam or plate specimens. Thus, the micromechanical and macromechanical behavior of composite beams and plates has received considerable attention [3-8].

Because of the complex geometries involved in micromechanical analyses of composites, the finite element method is the most widely used numerical technique. Adams [9] has pointed out some of the problems encountered in applying finite elements to micromechanical analysis. Hybrid elements have also been investigated [10]. Seshadri [11] reviewed the application of finite element methods in the general field of vibration analysis; Reddy [12] reviewed finite element modeling of structural vibrations. Finite elements have also been used for macromechanical analysis. Thornton [13] studied the effects of laminate asymmetry on vibration characteristics of panels. Baughn [14] analyzed the modal response of a composite automobile body. Chamis [15] modeled composite fan blades and reported good agreement with measurements.

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In related macromechanical analyses of composite structures, Bert found the optimum laminated plate design for maximization of the fundamental frequency [16] and estimated the fundamental frequencies of composite plates with various boundary conditions [17]. He also surveyed the dynamics of composite and sandwich panels [18]. Dharmarajan and Penzes [19] reviewed publications and computer programs dealing with dynamics of composite shell structures. The effects of biaxial stresses, fiber orientation, temperature, and frequency on dynamic properties of composites were investigated by Hong [20].

Although elastic analyses are necessarily restricted to dynamic stiffness and natural frequencies, the analysis of the total vibratory response must include damping. In the previous review [1], the authors pointed out the need for further study of damping mechanisms in composites. Birchak [21] reported on damping mechanisms in structural materials; Nielsen [22] reviewed damping mechanisms and predictions for filled plastics. More recently, a continuum model for hysteretic damping has been developed [23]. Hashin [24] developed an elastic-viscoelastic correspondence principle for lightly damped viscoelastic composite materials. The existence of a correspondence principle means that the elastostatic micromechanical analysis can be converted into a viscoelastic analysis simply by replacing constituent and composite elastic moduli with the corresponding complex viscoelastic moduli. Verification of the correspondence principle requires measurements of complex moduli of the composite and of the constituent materials.

One result of increased composite materials activity in the automotive industry has been the evolution of inexpensive chopped fiber reinforced plastics and hybrid composites with both chopped and continuous fiber reinforcement [25]. These new composites are often referred to as sheet molding compounds, or SMC. The static mechanical properties of these materials have been reasonably well characterized [26], but little is known about their dynamic properties. Some experimental results are referred to later, but no analytical work could be found. Due to the random orientation of short fibers in chopped fiber composites, their properties are generally more nearly isotropic than anisotropic. This leads to simplification in the elastostatic micromechanical analyses [27-31]. These analyses generally fall in the category of so-called effective modulus theories, which can be applied to dynamically loaded composites when the vibrational wavelength is long in comparison with the characteristic dimension of the composite microstructure. This rules out high frequency wave propagation. As mentioned before, no analytical work has been found on dynamic stiffness and damping of these materials. The elastic-viscoelastic correspondence approach appears to be worthy of investigation here. Bounds on the real and imaginary parts of the complex moduli of isotropic viscoelastic composites have been found by Roscoe [32]. Because these bounds are independent of phase geometry, they should apply to random short fiber composites as well. Additional references on bounds are available [1].

MEASUREMENT

Recent results. In many applications, the properties of fiber reinforced composites are more desirable than those of metals. Yet the acceptability of composites is often limited by lack of confidence in their reliability [33]. This is a consequence of the wide dispersion of static and dynamic properties found in nominally identical composite products. Thus, it is necessary to find test methods that provide the data needed to define and control such dispersion and to provide an indication of incipient failures. Some of the most promising test methods to date involve vibration response, which is governed by dynamic stiffness and damping. Measurements of these properties are also needed for verification of the micromechanics predictions.

A wide variety of experimental methods for finding dynamic stiffness and damping have been discussed by Gibson and Plunkett [1], by Bert and Clary [34], and by Brown [35]. Since these articles were published, several new techniques have evolved as a result of advances in instrumentation. Before discussing the new methods, however, it is appropriate to review recent experimental results obtained with the old test methods.

Gibson and Plunkett [36, 37] used a forced vibration resonant dwell technique to test unidirectional and crossplied E-glass/epoxy specimens in flexure. Good agreement with micromechanics predictions and

bounds was reported, and large amplitude tests showed that damping is extremely sensitive to microstructural damage. More recently, the same technique was used by Gibson [38] to find the complex moduli of E-glass/polyester sheet molding compounds and by Plunkett and Sax [39] to study modal interaction and nonlinear damping in aluminum, glass/epoxy and tool steel beams. An automated resonant dwell apparatus has been used to generate damping vs. amplitude data [40]. Vafai et al [41] used vibrating reed measurements to find the elastic moduli of wood in the longitudinal, radial, and tangential directions. Forced vibration response of composite plates has been used to find damping [42]. Cheng [43] used vibration tests and impact tests to find dynamic properties of composite laminates. It was concluded that vibration testing was preferable to impact testing. Georgi [44] reported on free vibration decay tests and forced vibration tests of several composites and composite structures. The effects of amplitude, temperature, vibration mode, frequency, air pressure, aspect ratio, and fiber orientation on damping were also studied.

The torsion pendulum continues to be a popular method for measurement of dynamic properties at low frequencies. James et al [45] developed a torsion pendulum which allows creep, fatigue, stress relaxation, elastic after-effect, static and dynamic moduli and hysteresis curves to be made at temperature and in vacuo. Bartesch and Williams [46] described an automated torsion pendulum apparatus for studying the effect of amplitude on damping. Adams et al [47] used a torsion pendulum to sense composite material deterioration via changes in damping. The changes in damping were more significant than corresponding changes in stiffness. Papadakis [48] reported on a balanced resonator, which is the flexural analog of the torsion pendulum. This device has a wider frequency range than the torsion pendulum and uses a specimen configuration identical to ASTM tensile test bars.

The effects of environmental conditions on static and dynamic properties of composites are currently receiving much attention by the aerospace and automotive industries. High temperatures and diffusion of moisture into resin matrix materials seem to be the major concerns. Two recent ASTM publications [49, 50] are devoted to environmental effects on advanced composites. Several papers in these publications are specifically concerned with dynamic and viscoelastic properties [51-53]. Maymon et al [51] showed that a hot, moist environment alters the stiffness of graphite/epoxy composites in matrix-controlled modes of deformation and substantially alters the damping in both matrix-controlled and fiber-controlled modes of deformation. Rehfield and Briley [54] compared environmental effects on damping and stiffness of graphite/epoxy with the corresponding effects on aluminum. Heller et al [55] found that the temperature dependence of the complex moduli of boron/epoxy and graphite/epoxy followed an Arrhenius relationship. Chatterjee and Kulkarni [56] studied the effects of environment on flutter of laminated composite plates. Except for these few papers, the work on environmental effects seems to have been centered on static testing. Some of the results of these static tests have important implications for dynamic behavior, however. For example, Whitney and Husman [57] conducted static flexure tests of graphite/epoxy beams and concluded that moisture and temperature can induce a change in failure mode from filament dominated to matrix dominated. Two mechanisms for these property changes had been identified earlier by Browning et al [58]. They found that absorbed moisture reduces the glass transition temperature of the matrix resin and also induces swelling which changes residual stresses in the composite. Adams and Miller [59] used a finite element analysis to show that moisture has a significant effect on residual stresses in the composite. One implication for dynamic behavior is that damping should be sensitive to all of these mechanisms, and damping measurements could prove to be useful in further studies of environmental effects. Probably the most important reason for finding the effects of the environment on damping is that the reliability of some composite structures may well be governed by them.

Because dynamic properties (especially damping) of composites are so sensitive to microstructural and interfacial behavior, various dynamic measurements have been used for nondestructive evaluation and for fatigue studies. The work of Adams et al [47] and Gibson and Plunkett [36] was referred to earlier. Schliekelmann [60] investigated the use of a resonance-impedance technique for quality control of fiber reinforced plastics. Ultrasonic spectroscopy was used by Cousins and Markham [61]. Adams et al [62] monitored changes in longitudinal natural

frequencies in several modes as specimens were progressively damaged. It was concluded that minor damage (damage voiding less than 1% of the cross-sectional area) could not be reproducibly detected due to inadequate frequency resolution. Cawley and Adams [63] used measurements of natural frequencies to detect, locate, and roughly quantify damage in composites. Dibenetto et al [64] correlated changes in stiffness and damping with the extent of fatigue damage and found that damping is particularly sensitive to debonding of fibers and matrix. Strain controlled fatigue tests have indicated that the fatigue life of composite materials may be dependent upon initial damping capacity [65, 66]. Yang and Caldwell [67] used damping measurements to detect damage in randomly excited structures. A correlation between the complex shear moduli and fracture energy of composite molding compounds at various temperatures was reported by Cawthorne and Harris [68].

As stated previously, little is known about dynamic properties of recently developed random short fiber composites or sheet molding compounds. Gibson [38] measured the complex flexural moduli of two SMC materials at low strains over the frequency range 10-1000 Hz. The complex moduli were essentially independent of amplitude and frequency within the ranges covered. Damping in the SMC was roughly an order of magnitude greater than the damping in aluminum of the same thickness. McLean and Read [69] tested a composite of discontinuous (but aligned) carbon fibers in a soft polymer matrix and found that both the loss modulus and the storage modulus were more than 100 times greater than the corresponding moduli for the unreinforced polymer. Measurements were supported by an energy analysis. The previously mentioned work of Cawthorne and Harris [68] is the only other source of experimental data on dynamic properties of short fiber composites that could be found. No data of this type were found for recently developed hybrid continuous/chopped fiber composites. Due to the projected high volume use of these materials in the automotive industry, there is a definite need for better characterization of dynamic properties, including environmental effects.

New techniques. The recent availability of digital FFT processors, many of which operate in real time, has motivated the development of new techniques for vibration testing and analysis. Plunkett [70] has reviewed recent advances in shock and vibration instrumentation. Because the operation of the FFT processor is essentially instantaneous over a selected bandwidth, broadband excitation signals from a random noise or impact source may be used to excite the specimen. Two-channel FFT processors execute a parallel frequency-by-frequency analysis of the input excitation and output response of the specimen under test; the ratio of the results is used to form the transfer function, or frequency response function. Dynamic stiffness and damping can be extracted from the transfer function by any of a number of methods [71-73]. Because the concept of a transfer function applies only to linear systems, nonlinear effects must be avoided in this type of analysis. Most of the references given here are concerned with vibrations and modal analysis of metallic structures, but the implications for composite materials testing are clear.

Impulse-transfer function methods have become popular for several reasons: no elaborate specimen fixture is necessary, no electromechanical shakers are needed, and testing time is greatly reduced. The transfer function for the structure (or specimen) is found by striking the structure with a hammer with a force transducer attached to its head. The signals from the force transducer and from a motion transducer at the desired location on the structure are fed into the dual channel FFT, which computes and displays the transfer function in real time [74-76]. Because the energy in an impulse is distributed continuously in the frequency domain, the transfer function is obtained instantaneously over the entire range of desired frequencies. Gordon and Wolfe [77] compared dynamic properties of aircraft structures as found by the impulse-transfer function technique with those obtained with the analog swept-sine method. Agreement was close, but the impulse technique resulted in a considerable savings of man-hours. Henderson and Drake [78, 79] have used both impulse and random excitation with FFT analysis to study damping of aerospace structures. With random excitation, as with impulse, all frequencies are excited, and the transfer function in the frequency domain is obtained quickly. Random excitation does require a shaker, however. The only reference found for impulse-transfer function testing of composite materials was the paper by Wolf and Carne [80]. They found the elastic con-

stants of SMC panels but did not use the data to find damping.

The main drawbacks to the impulse technique are the cost of FFT analyzers, the low signal-to-noise levels, and limited energy input at any discrete frequency. In some situations, multiple impact testing can be used to overcome the last two problems [81]. The importance of frequency resolution in obtaining damping measurements from transfer functions has led to development of a measurement enhancement technique called zoom analysis [76, 82]. Zoom analysis lets one selectively magnify a portion of the displayed transfer function, usually in the neighborhood of a resonance. Zoom analysis is an absolute necessity if input excitation is weak, if modal coupling is strong, or if the system is lightly damped.

All the new FFT-based techniques just described make use of analog transducers and analog-to-digital pre-processors. It would seem that the next logical step would be the development of all-digital vibration measurement systems. Digital transducers, which function discretely by a switching action, are insensitive to temperature changes within the operating temperature limits of the pulse shaping circuitry. Analog transducers function continuously by amplifying action, tend to drift, and are sensitive to electrical impedance changes. A noncontacting transducer is also desirable for damping measurements. Few noncontacting digital transducers are presently available. A recently developed laser micrometer [83] appears to have the desired characteristics.

CONCLUSION

Analytical and experimental characterization of dynamic mechanical properties of composite materials is taking on added importance as new composites are developed, concerns about producibility and reliability increase, and environmental effects become more important. Although much effort has been directed at the experimental techniques in the past, it has been developments in the electronics industry that have accelerated the research efforts toward the isolation and control of the parameters that influence the reliability of these tests. One distinction of past, present, and future tests is the type of electronics associated with the test instrumentation and transducers. Past tests relied on analog electronics; present tests use a combination of analog and digital electronics; and future tests may well complete the transformation to digital electronics. After reviewing all the various measurement techniques, one must conclude that, more than ever before, there is a need for standardized tests for dynamic stiffness and damping.

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LITERATURE REVIEW

survey and analysis of the Shock and Vibration literature

The monthly Literature Review, a subjective critique and summary of the literature, consists of two to four review articles each month, 3,000 to 4,000 words in length. The purpose of this section is to present a "digest" of literature over a period of three years. Planned by the Technical Editor, this section provides the DIGEST reader with up-to-date insights into current technology in more than 150 topic areas. Review articles include technical information from articles, reports, and unpublished proceedings. Each article also contains a minor tutorial of the technical area under discussion, a survey and evaluation of the new literature, and recommendations. Review articles are written by experts in the shock and vibration field.

This issue of the DIGEST contains review articles on recent research in composite and sandwich plate dynamics; and optimization techniques for shock and vibration isolator development.

Dr. C.W. Bert of the University of Oklahoma has written an article about recent research in composite and sandwich plate dynamics. This paper surveys literature concerning dynamics of plate-type structural elements of either composite material or sandwich construction. Papers from 1976 through early 1979 are reviewed.

Mr. R.W. Mayne of SUNY at Buffalo has written an article concerning optimization techniques for shock and vibration isolator development. The purpose of this effort is to summarize work that has been published on this subject since 1976.

RECENT RESEARCH IN COMPOSITE AND SANDWICH PLATE DYNAMICS

C.W. Bert*

Abstract - This paper surveys literature concerning dynamics of plate-type structural elements of either composite material or sandwich construction. Papers from 1976 through early 1979 are reviewed. Special attention is given to rectangularly orthotropic, cylindrically orthotropic, and anisotropic plates; laminated plates; thick and sandwich plates; and nonlinearities. Free vibration, harmonic and random forced vibration, thermally and flow induced vibration (flutter), and impact are also treated.

The fundamentals of the mechanics of composite and laminated plates have been discussed in a previous survey [1] and are not repeated. No books have yet been published in the subject area; the survey thus consists largely of papers in the open literature and some reports. The following topics are excluded: strictly in-plane motion, acoustic wave transmission, and failure due to impact and fatigue loadings.

SMALL-DEFLECTION MOTION OF THIN, SYMMETRICALLY LAMINATED, RECTANGULARLY ORTHOTROPIC PANELS

These panels are the simplest and most extensively investigated of thin composite-material plates and are often called orthotropic plates. The panels can be an aligned single layer, an aligned parallel-ply laminate, or a symmetrical cross-ply laminate. Laminate symmetry about the plate midplane ensures the absence of bending-stretching coupling; aligned orthotropic material symmetry prevents shear-normal coupling. Thus, in the absence of applied shear and in-plane loading, the governing equation of motion can be written as

$$D_{11}w_{,xxxx} + 2(D_{12} + 2D_{66})w_{,xxyy} + D_{22}w_{,yyyy} + \bar{\rho}hw_{,tt} - p = 0 \tag{1}$$

The D_{ij} are the plate flexural and twisting rigidities, h is the plate thickness, p is the normal pressure, t is time, w is the plate deflection, $(\ )_{,xxyy}$ denotes $\partial^4(\ )/\partial x^2 \partial y^2$, x and y are rectangular position coordinates coinciding with the material-symmetry directions, and $\bar{\rho}$ is the mean density.

In terms of energy the analogous expression is

$$U_i + U_e = T \tag{2}$$

The internal strain energy U_i, work U_e done by the external force, and kinetic energy T are given respectively as

$$\begin{aligned} U_i &= (1/2) \iint (D_{11}w^2_{,xx} + 2D_{12}w_{,xx}w_{,yy} + D_{22}w^2_{,yy} + 4D_{66}w^2_{,xy})dx\,dy \\ U_e &= -\iint p\,w\,dx\,dy \\ T &= (1/2) \iint \bar{\rho}\,h\,w^2_{,t}\,dx\,dy \end{aligned} \tag{3}$$

Free Vibration

A method for deducing orthotropic solutions from corresponding isotropic solutions was introduced independently in Japan [2, 3] and in the U.S. [1, 4]. This approach enables the vast literature on free vibration of isotropic plates of various planforms to be utilized to predict approximate natural frequencies for orthotropic plates of the same planforms. The accuracy of the method has been verified for the specific geometries listed in the Table. The effects of biaxial inplane loads (tensile or compressive) were later incorporated into the method [5], thus generalizing previous work on buckling of orthotropic plates [6, 7].

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Table. Applications of Isotropic-to-Orthotropic Deduction Technique

Planform Geometry	Boundary Conditions	Reference Number
Rectangular	Fifteen Combinations of clamped and simply supported	1, 4
Parallelogrammic	Simply supported	2
Elliptic	Clamped	1, 3, 4
Right triangular	Clamped and simply supported	1, 4

Insofar as the development of relatively new methods of analysis is concerned, Dharmarajan and Chou [8] extended the method of constant deflection lines -- originated for deflection [9] and free vibration of isotropic plates [10] -- to orthotropic plates. They applied it to both clamped-edge and simply-supported-edge elliptic-planform plates. The main disadvantage of this method is that it can be used to determine only the fundamental frequency.

Another method, not actually new but seldom applied to vibration of plates, is the Kantorovich method [11], known as the Lévy method in static plate deflection theory [12]. This method has recently been applied to free vibration of orthotropic plates [13]. Solutions were obtained by finite differences with respect to one position coordinate. Uniform-thickness rectangular plates with seven different boundary conditions and linearly tapered rectangular plates with simply supported edges were studied. Values for the first six natural frequencies were in fairly close agreement with those obtained using other methods.

Vijayakumar and Ramaiah [14] used a variation [16] of Bolotin's asymptotic method [15] to obtain an initial solution; this solution became the trial function in the Rayleigh and Rayleigh-Ritz methods. The results for clamped rectangular plates were compared with those obtained previously. Compared with 36-term Rayleigh-Ritz results [17], the modified Bolotin estimates for the fundamental frequency were as much as 4.8% in error (always on the low side); the results with the variation [14] are only 0.32% in error (sometimes lower, other times higher). It is significant that a well-known simple formula [18] gave frequency values as much as 50% too high.

In addition to work mentioned above [13], varying thickness plates have also been investigated; approximate fundamental-frequency expressions were derived for simply supported [19] and clamped [20] edge conditions.

Sakata [21] treated a multi-bay continuous rectangular panel. He considered simple supports at the $y=0$ and $y=b$ edges, free or elastically restrained edges at $x=0$ and $x=a$, and simple supports at the intermediate supports $x=a/N$, $2a/N$, .. , $(N-1)a/N$.

Laura and Luisoni [22] used the Rayleigh-Ritz method in conjunction with polynomial modal functions to analyze a rectangular plate with different values of elastic restraint at the edges and subjected to in-plane forces. Beam functions were used in conjunction with the Rayleigh-Ritz method to treat in-plane-loaded rectangular plates with various combinations of boundary conditions [23]. A conformal-mapping technique used to analyze irregularly shaped plates under in-plane forces [24] led to numerical results for the case of a rectangularly orthotropic plate of circular planform. However, the results appear to contain some numerical error [25].

With the growing industrial importance of the finite-element method, it is not surprising that its use in composite-plate vibration analyses is increasing. A simplified mixed rectangular element has been applied to free vibration of rectangular plates [26]. A combination of triangular and rectangular elements have been used for the vibration of a cantilever plate representative of a delta-planform airplane wing [27].

Forced Vibration

Relatively few investigations on forced vibration have been reported recently, except for some analytical work [28] and experimental work [29] on response to random excitation.

An equivalent viscous damping approach was used to predict response of a simply-supported rectangular plate to a sinusoidal point load normal to the plate at its center [30].

Two investigations concerned with thermally induced vibrations were on rectangular [31] and equilateral triangular [32] plates. The latter is severely limited by the assumption that $2(D_{12} + 2D_{66}) = (D_{11} D_{22})^{1/2}$. Related work on the effect of thermal stresses induced by steady-state sinusoidal loading has been reported [33].

SMALL-DEFLECTION MOTION OF THIN, SYMMETRICALLY LAMINATED, RECTANGULARLY ANISOTROPIC PANELS

Relatively very little work has been conducted recently. The governing equation of motion for this class of panel is identical to that in equation (1) with the addition of two bending-twisting coupling terms on the left side: $4D_{16}w_{,xxxy}$ and $4D_{26}w_{,xyyy}$.

In optimization studies of rectangular plates having the symmetric balanced angle-ply lamination arrangement, for instance $\theta/-\theta/-\theta/\theta$, both simply supported [34] and clamped [35] edges were considered. In each case the optimal lamination angle (θ) depends upon the plate aspect ratio as well as the laminate material.

Laura and Grossi [36] considered rectangular plates with supported edges having elastic rotational constraints. However, the latter conditions are satisfied only approximately. Solution was obtained by the Rayleigh-Ritz method with polynomial modal functions. For cases in which comparisons with previous solutions were possible, sufficiently good agreement for engineering purposes was obtained.

In many aerospace, marine, and automotive applications, cutouts are necessary for lightening and access. Thus, work on rectangular panels with rectangular cutouts is of practical importance [37, 38]. The cutout is assumed equivalent to a certain displacement-dependent external loading. Both simply-supported [37] and clamped [38] edges and sinusoidally forced and free vibrations were treated. Results in graphical form depicted the effects of plate material, orientation, and plate and cutout geometry.

In analyses of the flutter of rectangular panels under high-Mach-number supersonic conditions, numerical results were presented for boron-epoxy, graphite-epoxy, and boron-aluminum unidirectional materials at various orientations [39].

SMALL-DEFLECTION MOTION OF THIN, UNSYMMETRICALLY LAMINATED RECTANGULARLY ORTHOTROPIC AND ANISOTROPIC PANELS

Finite-element analyses are now being used for this class of plate [40, 41]. The application of the NASTRAN CQDPLT element to rectangular-planform cantilever plates gave excellent agreement with experimental results for boron-epoxy panels [40]. For this set of boundary conditions, the reduced stiffness simplification was shown to be adequate. In this approach the direct bending-stretching coupling terms are omitted, but the actual bending stiffness matrix $[D_{ij}]$ is replaced by the reduced one $[D_{ij}^*]$ defined as follows

$$[D_{ij}^*] = [D_{ij}] - [B_{ij}][A_{ij}]^{-1}[B_{ij}]$$

NASTRAN CTRIA 2 was used to analyze the free vibration of cantilever compressor blades [41]. Results were in good agreement with resonant frequencies and nodal patterns obtained experimentally by holography.

The Rayleigh-Ritz method was used to determine the resonant frequencies of clamped cross-ply laminated plates of circular planform [42].

The Galerkin method was used to obtain Fourier-form solution for the flutter of arbitrarily laminated thin plates [43]. Graphical results showed the effects of lamination angle, lamination arrangement, and flow direction on the flutter parameter for plates laminated of glass-epoxy, boron-epoxy, and graphite-epoxy.

SMALL-DEFLECTION MOTION OF THIN, SYMMETRICALLY OR UNSYMMETRICALLY LAMINATED, CYLINDRICALLY ORTHOTROPIC OR ANISOTROPIC PANELS

Apparently it would be difficult to manufacture a uniform-thickness plate that is cylindrically orthotropic; i.e., having the material-symmetry axes oriented in the radial and circumferential directions. Nevertheless, vibrational analyses of such plates, either single-layer/symmetrically laminated [44-46] or arbitrarily laminated [47] have been reported. It would seem to be even more difficult to construct

a cylindrically anisotropic plate; i.e., having a full array of elastic properties (no symmetries or zero values) with respect to a cylindrical coordinate system. However, the vibrations of this class of plate have also been analyzed [49].

Prathap and Varadan [44] considered the axisymmetric free vibration of a solid circular plate of cylindrically orthotropic material. Comparison of the results obtained by the Rayleigh energy method (called the Lagrangian method by the authors) with those obtained by the Galerkin method revealed the source of some discrepancies in some existing analyses of this problem. The method of Frobenius for the nonaxisymmetric case [45] was used to obtain results that have been criticized [44].

Ramaiah and Vijayakumar [46] extended previous work to the vibration of concentric annular cylindrically orthotropic plates.

For cylindrically anisotropic plates with small flexural rigidities and subject to high in-plane loads, the numerical-perturbation method of matched asymptotic expansions was used to study the free vibrations [48].

EFFECTS OF THICKNESS-SHEAR DEFORMATION ON SMALL-DEFLECTION MOTION

It has long been accepted that thickness-shear deformation plays a prominent role in sandwich panels; i.e., those with one or more thick, highly flexible cores and one or more thin, relatively rigid facings. However, this effect is often important in composite-material laminated panels as well; i.e.; those with all layers of equal thickness. In fact, it is important even in single-layer panels of composite material due to their very low ratio of shear modulus to Young's modulus as compared to isotropic materials.

Symmetric Laminates

A Galerkin-type approach was used to study the free vibration of rectangular plates of rectangularly orthotropic material and subjected to any combination of simply supported, elastically supported, or clamped edge conditions [49]. Rotatory inertia was included.

Hinton extended the finite-strip method to the symmetrically laminated anisotropic case [50] and also developed an analogous finite element [51].

The Mindlin-Goodman procedure [53] was used to obtain a solution for the transient response of an infinite long plate strip simply supported along the sides [52]. The effects of pulse shape (rectangular, triangular, and sinusoidal) and pulse dwell time on dynamic load factor, maximum deflection, maximum bending stress, and maximum interlaminar shear stress were investigated. A somewhat similar analysis has been reported for the plane-strain case in the presence of residual thermal stresses [54]. The results indicated that thermal stresses are usually detrimental to dynamic behavior.

Unsymmetric Laminates

There has been considerable activity in the case of free vibration of rectangular-planform plates. Bert and Chen [55] presented a closed-form solution for a certain kind of simply supported edges. The results of a mixed finite element to this problem [56] were in good agreement. An eight-node, 40-degree-of-freedom thick-plate element was in good agreement with experimentally determined natural frequencies [57]. The British Program VIPASA has been extended [58].

Venkatesan and Kunukkasseril [59] analyzed the free vibration of a circular-planform plate laminated of different isotropic materials. Symbolic manipulation techniques in conjunction with a Rayleigh-Ritz analysis of a clamped elliptic plate have been used [60, 61].

A thick multilayer laminate theory has been formulated and used to predict the natural frequencies of a simply-supported rectangular plate [62]. Bending, traction, and shear effects are included for each layer, and continuity of stresses and displacements at the interlaminar interfaces is maintained. Dong and Pauley [63] used elements through the thickness to investigate plane wave propagation in thick, laminated plates.

The forced response of a symmetric cross-ply substrate was analyzed with a constrained damping layer [64].

Sandwich Panels

Earlier literature on dynamics of sandwich panels is extensive [1, 65]; recent analyses have thus been directed toward specialized aspects -- for example, the effect of thickness-normal flexibility of core material [66]. The effect on impact is somewhat analogous to the impact of a thickness-normal-rigid sandwich plate on a free surface of liquid.

A rectangular sandwich panel with unsymmetric orthotropic facings was subjected to a time-harmonic point loading normal to the plate [67]. Calculations for a sandwich with one facing of aluminum, the other of steel, and a polyvinyl chloride core indicated that the effect of symmetric modes on antisymmetric ones was not pronounced.

Lee and Chang [68] investigated the dispersion relations for a sandwich with symmetric facings and isotropic materials throughout. The material arrangement was typical of electrostatically charged precipator plates; i.e., a heavy, stiff core (the plate itself) and a light, flexible facing (coatings of dust particles adhering to the plate). This is the converse of the material arrangement typical of structural applications.

Relatively compact electronic devices are sometimes mounted on sandwich panels. It is of interest, therefore, to study the effect of a mass-spring-dashpot system attached at an arbitrary point. The damped free vibration of one such system had a rectangular plate with symmetric orthotropic facings and orthotropic core [69].

Chen and Carne [70] conducted a finite-element and experimental investigation of an open sandwich panel consisting of a single flat plate with a trapezoidal corrugated member attached. An epoxy-adhesive bonded structure had a greater stiffness than a spot-welded one.

A number of recent papers have been concerned with the damping behavior of sandwich panels. In an experimental investigation of a foam-core panel, and on the basis of a beam analysis, the system was believed to behave as a distributed-parameter tuned dynamic absorber [71]. At low frequencies, the behavior was dominated by thickness-normal action analogous to a spring-mass system; at higher frequencies the system behaved more like a homogeneous beam.

Damping has been incorporated into dynamic analyses of sandwich panels in three ways in recent work:

- Use of single composite loss factor [72, 73]. The main disadvantage of this approach is that the composite loss factor is most conveniently determined empirically from experiments.

- Use of a complex-modulus approach for the core-material shear moduli only [74, 75]. The main disadvantage of this approach is that it categorically neglects any damping in the facings.

- Use of a complex-modulus approach for the Young's modulus of the facing material as well as the shear modulus of the core material [76]. In any case, this is the most accurate model, especially with facings of polymer-matrix composite material. Unfortunately, however, the work was limited to isotropic facings and an isotropic core.

Flutter of a sandwich panel was analyzed [77] using the finite-element method.

EFFECTS OF GEOMETRIC NONLINEARITY

Of the two sources of nonlinearity in the dynamics of composite-material plates, the most common is geometric nonlinearity at finite deflections due to the stiffening membrane action when the plate edges are prevented from undergoing any in-plane displacement. The effect is a hardening-spring action that causes the natural frequencies to increase as the amplitude of motion is increased.

Thin Laminates

A variety of solutions for uniform-thickness, rectangularly orthotropic thin plates undergoing large-amplitude vibration have recently appeared. It is gratifying that only one [78] of these investigations used the overworked Berger's hypothesis, which has been shown to be unreliable in many cases [1]. Various methods have been applied to rectangular orthotropic plates: the Galerkin technique [79, 80], the perturbation method [81], and a simplified 16-degree-of-freedom rectangular conforming finite element [82]. The latter kind of element has also been used with cylindrically orthotropic plates [83].

Radially tapered cylindrically orthotropic circular plates were treated analytically [84] and with finite elements [85]. Annular plates with two different nonlinear tapers were used to obtain solutions by a combination of the Kantorovich method and the Newton-Raphson iteration scheme [84]. A linear-tapered solid circular plate was treated with finite elements [85]. Two large-amplitude analyses of unsymmetric laminates have appeared [86, 87]. In one case antisymmetric cross-ply rectangular plates with two opposite edges simply supported and the other two edges clamped were studied using the Galerkin technique. Both stress-free and immovable in-plane edge conditions were included.

Most of the analyses mentioned above involved only one term in position and thus neglected the effects of modal coupling. An exception is the work of Chia and Prabhakara [87], who presented multiple-mode solutions for rectangular plates of both antisymmetric angle-ply and antisymmetric cross-ply with both simply supported and clamped edges. Although the effect of modal coupling on the nonlinear frequencies of isotropic plates is not significant, it can be significant for composite panels, especially clamped-edge high-modulus laminates.

Thick Laminates and Sandwich Panels

Sathyamoorthy [88, 89] included the effects of thickness shear deformation and rotatory inertia for symmetrically laminated rectangularly orthotropic plates. Unfortunately, he used the Berger hypothesis, rather than working directly with the dynamic version of the von Karman equations. The Berger hypothesis was also used to derive a relatively simple frequency expression for a simply supported rectangular plate of isotropic symmetric sandwich construction [90].

In an analysis of the nonlinear dynamic snap-through symmetric buckling of a simply supported rectangular plate of isotropic symmetric sandwich structure, the plate is assumed to have a slight initial curvature [91]. A double Fourier series in position and Houbolt's timewise integration scheme was used.

EFFECTS OF NONLINEAR MATERIAL BEHAVIOR

Physical (material behavior) nonlinearity may be due to nonlinear stress-strain relations such as exemplified by ordinary yielding or that due to the softening nonlinearity encountered in the shear stress vs. shear strain relation for certain composites.

Zak [92] considered physical nonlinearity in the form of orthotropic elastoplastic material behavior. He also considered lamination effects, thickness shear deformation, and geometric nonlinearity. His analysis is based on the use of numerical timewise integration and a uniform-thickness quadrilateral finite element stacked in the thickness direction to represent the composite layers.

Sun and Shafey [93] considered material-behavior nonlinearity in the form of an additional cubic shear-strain term in the thickness shear stress-strain relation. They investigated harmonic wave propagation, formation of shock waves, and free vibrations. A much more elaborate analysis included up to fourth-order elastic constants -- i.e., up to cubics of the strains [94].

TRENDS AND SUGGESTIONS FOR FUTURE RESEARCH

The following trends are notable since the first review of this series [1]:

- Use of the finite element method for both linear and nonlinear problems [95]
- Increased study of such practical complications as cutouts, attached mass-spring damper systems, elastically supported edges, and random excitation
- Increased activity in the area of geometrically nonlinear problems

The author believes that the following aspects should be investigated more fully:

- More general lamination schemes with attention toward their use in optimal design syntheses for such multiple conditions as flight loadings, noise, buckling, and flutter
- More realistic material models, with respect to both effects of frequency and temperature on stiffnesses and damping and to fatigue

properties and even the nonlinearity of the stress-strain relations

- Interactions between vibration and material flaws, for example, crack propagation under various kinds of vibratory excitations

- Experimental verification of analyses, as well as vibration testing as a system identification technique

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OPTIMIZATION TECHNIQUES FOR SHOCK AND VIBRATION ISOLATOR DEVELOPMENT

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Abstract - The purpose of this effort is to summarize work that has been published on optimization methods with application to shock and vibration isolation since 1976. The article is divided into three sections: the first deals with nonlinear programming methods that are basic tools for engineering optimization problems of all types; the second is concerned with time domain methods of isolator optimization as evolved from optimal control theory; and the third focuses on those cases where isolation systems are considered in the frequency domain.

The first review article concerning optimization methods with application to shock and vibration isolation appeared in 1976 [1]. That article provided a basic introduction to the literature. In each of the three sections of the present article, a description of problems and techniques of interest is given; emphasis is on recent publications. Somewhat more complete introductory information was published previously [1].

NONLINEAR PROGRAMMING

The basic problem in design optimization can be described in the following mathematical form:

$$\underset{\underline{x}}{\text{minimize}}\ f(\underline{x}) \tag{1}$$

subject to

$$g_i(\underline{x}) \leqslant 0 \qquad i = 1, 2, \ldots, p \tag{2}$$

and

$$h_j(\underline{x}) = 0 \qquad j = 1, 2, \ldots, q \tag{3}$$

The n design variables contained in the vector $\underline{x}$ are to be adjusted to minimize the objective function or design criterion $f(\underline{x})$. The constraints of equations (2) and (3) must also be satisfied by the optimum values of the design variables. For isolator applications a typical problem might include design variables that are spring and damper coefficients with an objective function of minimum relative displacement and a constraint reflecting the maximum allowable acceleration. Techniques developed for the general solution of problems of this type are typically referred to as nonlinear programming methods -- search strategies or hill climbing methods. Typically a computer algorithm is utilized in an actual solution.

The more popular techniques for solving optimization problems described by the equations were summarized in 1976 [1]. Since that time there have been two significant developments in general purpose optimization methods. These developments do not involve new strategies but rather a recognition of the capabilities of methods previously described. Recent studies of the generalized reduced gradient method and multiplier techniques for constrained optimization indicate that they can be applied efficiently.

The Reduced Gradient

The comparative study of optimization algorithms by Sandgren and Ragsdell [2, 3] contained a variety of methods, including some based on the same theoretical approach but coded for computation by different individuals or groups. A striking result of this study is that the most efficient algorithms of a variety of realistic optimization problems were based on the generalized reduced gradient strategy. Another important aspect of the study is that finite difference computations were used for all the gradient evaluations, as is necessary in most applications.

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The reduced gradient method was originally described by Wolfe [4] for problems with linear constraints; it then was generalized by Abadie [5] to handle nonlinear constraints. A similar but independent procedure has also been described by Wilde and Beightler [6]. The first step in the generalized reduced gradient method involves separating the inequality constraints of equation (2) into those that simply reflect limits on the design variables themselves and those that are more complicated functions of the design variables. The more complex inequality constraints are then transformed into equality constraints by adding new slack variables to the list of design variables and requiring that the slack variables be positive. For example, $g_1(\underline{x})$ could become $h_{q+1}(\underline{x}) = g_1(\underline{x}) + x_{n+1} = 0$; with x_{n+1} positive the original inequality $g_1(\underline{x}) \leqslant 0$ is satisfied. With these changes, a modified optimization problem can be stated:

$$\underset{\underline{x}}{\text{Minimize}}\ f(\underline{x}) \tag{4}$$

subject to

$$h_j(\underline{x}) = 0 \qquad j = 1, 2, \ldots, Q \tag{5}$$

and

$$x_{k\min} \leqslant x_k \leqslant x_{k\max} \qquad k = 1, 2, \ldots, N \tag{6}$$

In this modified problem, the Q equality constraints contain the q original equalities plus the additional inequality constraints with slack variables added. The N design variables are now the original n design variables plus the slack variables. Upper and lower limits have been specified for each variable; the lower limits of the slack variables are set equal to zero.

From equations (4) to (6) it is clear that only N-Q design variables can be independently adjusted because Q conditions are imposed by the equality constraints. The design vector is separated into two portions, $\underline{x}^T = [\underline{z}^T \underline{y}^T]$, where the N-Q variables contained in the vector $\underline{z}$ have been selected for independent adjustment and are referred to as decision variables. The remaining Q variables, designated state variables, are contained in $\underline{y}$ and can be determined by solution of equations (5) when the vector $\underline{z}$ is specified. The reduced gradient search is begun with an initial set of values for all design variables that satisfy the equality constraints. A one-dimensional search is then begun: the decision variables $\underline{z}$ are varied as corrections are made in the state variables $\underline{y}$ to maintain the equality constraints. The reduced gradient vector, which reflects this correction process, is obtained by modifying the objective function gradient with respect to $\underline{z}$. This modification attempts to account for changes in the objective function resulting from the adjustments in $\underline{y}$ needed to maintain the equality constraints as $\underline{z}$ fluctuates from the initial feasible design. The reduced gradient vector is

$$\nabla f_r = \nabla f_z - [H_y^{-1} H_z]^T \nabla f_y \tag{7}$$

where $\nabla f_z^T = [\partial f/\partial z_1, \partial f/\partial z_2, \ldots, \partial f/\partial z_{N-Q}]^T$ and $\nabla f_y^T = [\partial y/\partial y_1, \partial f/\partial y_2, \ldots, \partial f/\partial y_Q]^T$.

The matrices are

$$H_y = \begin{bmatrix} \frac{\partial h_1}{\partial y_1} & \frac{\partial h_1}{\partial y_2} & \cdots & \frac{\partial h_1}{\partial y_Q} \\ \vdots & & & \\ \frac{\partial h_Q}{\partial y_1} & \frac{\partial h_Q}{\partial y_2} & \cdots & \frac{\partial h_Q}{\partial y_Q} \end{bmatrix}$$

and

$$H_z = \begin{bmatrix} \frac{\partial h_1}{\partial z_1} & \frac{\partial h_1}{\partial z_2} & \cdots & \frac{h_1}{\partial z_{N-Q}} \\ \vdots & & & \\ \frac{\partial h_Q}{\partial z_1} & \frac{\partial h_Q}{\partial z_2} & \cdots & \frac{\partial h_Q}{\partial z_{N-Q}} \end{bmatrix}$$

The reduced gradient vector ∇f_r of equation (7) is the basis for the series of one-dimensional searches in decision variable space. These searches can be patterned after any suitable unconstrained search method; e.g., Davidon-Fletcher-Powell [7]. However, many solutions of the system of nonlinear equality constraint equations must be made to obtain the values of $\underline{y}$ necessary for a feasible design. In addition, swapping variables between state and decision status is necessary as variables attain or leave their upper or lower limits. The procedure becomes complex but apparently pays off in an efficient search of the design space.

Multipliers

Penalty functions are often convenient in dealing with constrained optimization problems. These methods modify an objective function in a design problem to penalize violated constraints. The problem can then be solved by unconstrained optimization methods; the penalty term accounts for the constraints. Hestenes [8] and Miele et al [9] have described a penalty function method based on multipliers for equality constrained problems. For a minimization problem based on equations (1) and (3), this penalty function can be written as

$$\phi(\underline{x}, \lambda_{jk}, c_k) = f(\underline{x}) + \sum_{j=1}^{q} \lambda_{jk} h_j(\underline{x}) + c_k \sum_{j=1}^{q} [h_j(\underline{x})]^2 \tag{8}$$

The λ_{jk} and c_k are parameters that control the penalty function. Equation (8) refers to the kth iteration in a sequence of unconstrained minimizations that converge to the constrained optimum. Relationships must be provided to define λ_{jk} and c_k in terms of k.

The term in equation (8) containing the multiplier λ_{jk} is related to the Lagrange multiplier. In combination with the more traditional penalty term it helps reduce numerical difficulties associated with sequential increases in c_k. An excellent survey article [10] describes the background of this method. Additional work [11-13] has extended this approach to inequality constraints and indicates that methods of this nature have promise in engineering design.

In one algorithm [12], the penalty function, including inequality and equality constraints, takes the form

$$\phi(\underline{x}, \sigma, \tau) = f(\underline{x}) + R \sum_{i=1}^{p} \left\{ <g_i(\underline{x}) + \sigma_i>^2 - \sigma_i^2 \right\} + R \sum_{j=1}^{q} \left\{ [h_j(\underline{x}) + \tau_j]^2 - \tau_j^2 \right\} \tag{9}$$

The bracket function is defined so that $<\alpha> = 0$ for $\alpha < 0$ and $<\alpha> = \alpha$ for $\alpha \geqslant 0$. R is a fixed constant for weighting the constraints relative to the objective function. The parameters σ and τ are defined at the start of the kth unconstrained minimization according to

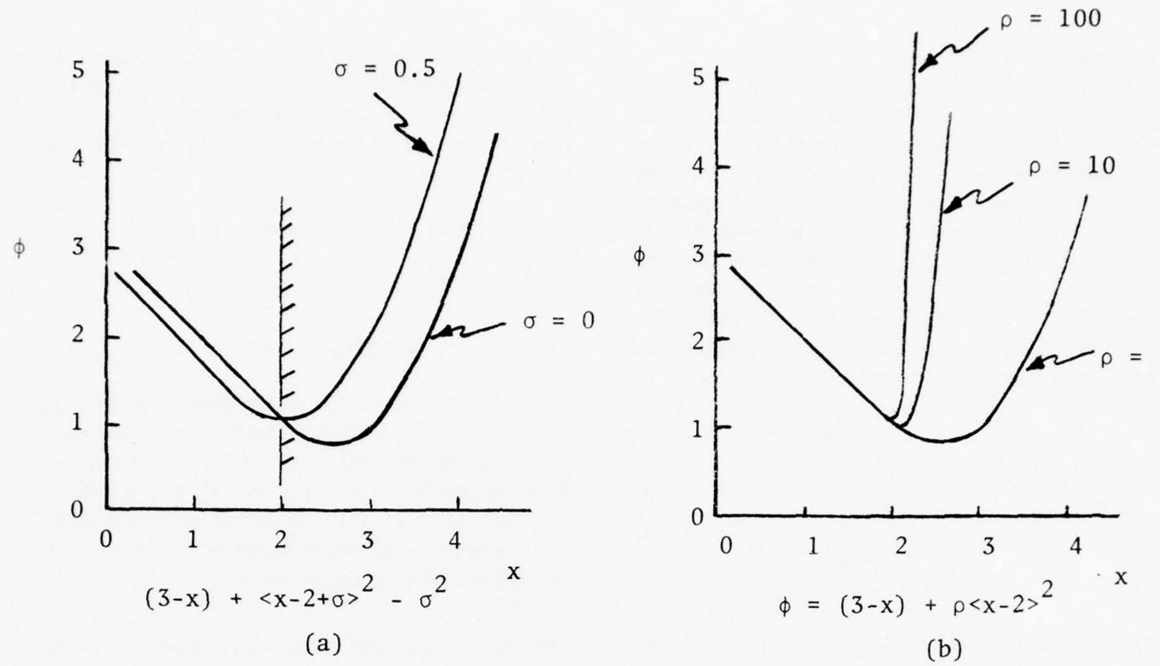
$$\sigma_i(k) = <g_i(\underline{x}_{k-1}) + \sigma_i(k-1)> \tag{10}$$

and

$$\tau_j(k) = h_j(\underline{x}_{k-1}) + \tau_j(k-1) \tag{11}$$

where $\underline{x}_{k-1}$ is the value of the design vector after the (k−1)th minimization. Convenient starting values for the parameters are $\sigma_i(0) = \tau_j(0) = 0$. A number of iterations minimizes equation (9), and equations (10) and (11) are used to update σ_i and τ_j after each unconstrained minimization until convergence to the constrained optimum occurs.

The advantage of this multiplier approach compared to the traditional exterior and internal penalty function methods is that the final unconstrained searches are performed on well-behaved functions instead of steep-walled valleys resembling optimization test problems. The difference can be seen in the trivial one-dimensional problem of minimizing $f(x) = (3-x)$ subject to the constraint $g(x) = (x-2) \leqslant 0$. Equation (9) in this case becomes $\phi = (3-x) + < x-2+\sigma >^2 - \sigma^2$ if $R = 1$. For a starting value of $\sigma = 0$, the modified function ϕ appears as in (a) of the figure, with a minimum at $x = 2.5$. According to equation (10), σ equals 0.5 with the resulting ϕ (see (a) of the figure). This function has a minimum at the constrained optimum. Note that the curves have a similar but shifted appearance and that the second is not steeper than the first. This is contrast to the traditional exterior penalty function, in which $\phi = (3-x) + \rho < x-2 >^2$, and convergence to the constrained optimum occurs as $\rho \rightarrow \infty$. This is shown in (b) of the figure; the function becomes steeper just outside the constraint with increasing ρ. This steepness creates difficulties in unconstrained optimizations for multidimensional problems. Work by Fujimoto and Fujii [13] on a similar penalty algorithm shows a comparison of function contours in two dimensions, again indicating better behavior for the new approach. Comparative results on optimization problems [10, 12] show improvements over the traditional penalty function.



Graphic Representations of the Multiplier Approach
and the Exterior Penalty Function Method

Other Trends

Several recent papers in optimization for mechanical engineering application indicate a need to develop a physical or mathematical feel for optimization problems. This need goes beyond solving optimization problems by search methods; development of principles and criteria for confident identification of an optimum design is the goal. It is a response to the difficulties of actually applying nonlinear programming where problems of accurate convergence and possible local minima are always of concern. Wilde and Papalambros [14, 15] have applied the ideas of geometric programming to establishing the concepts of monotonicity and dominance as principles of optimal design. Ellis [16, 17] applied Johnson's method [18] and reduced some fairly large problems to readily comprehendible size. Afimiwala and Mayne [19, 20] used interactive graphics to reduce computer time, increase confidence in the solution of optimization problems, and develop a physical feel for the optimization. Objective function and constraint contours can be plotted for various two-dimensional views of a design space, and nonlinear programming algorithms can be monitored interactively.

TIME DOMAIN METHODS

An isolation system can be conveniently optimized for transient response behavior. The system is simulated numerically, and a nonlinear programming algorithm is applied to adjust the design parameters. Relatively modest computational skills are required, yet satisfactory results can be obtained for smaller problems. However, as problems exceed one or two degrees of freedom, the computer time required can become prohibitively expensive. Efforts have been aimed at developing more attractive procedures for transient response design of larger systems. These efforts have been based largely on ideas developed earlier for optimal control applications [21-23] and have been discussed [1].

Shock Isolation

A problem considered in recent work [24] is a shock isolation system whose stiffnesses, damping coefficients, and masses are to be adjusted to provide an optimum transient response. The dynamic equations for the system are considered in the form

$$P(\underline{x})\dot{\underline{z}} = F(t, \underline{z}, \underline{x}) \quad (12)$$

The dynamic state variables $\underline{z}$ usually describe the positions and velocities of masses in the system; the initial conditions on the masses must be given as part of the problem definition. The vector $\underline{x}$ contains the design variables; $P(\underline{x})$ is a matrix whose elements depend on the design variables. The right side of this equation is very general and contains the system forcing function or input as a function of time; it also depends on the dynamic state variables, as well as $\underline{x}$. This equation can represent a nonlinear system, as indicated by its general form. Emphasis in this optimization is on dealing with maximums during the dynamic response because maximum accelerations and maximum relative displacements are often important considerations in isolator design. The objective function is in the form

$$f(\underline{x}) = \max_t F_o[t, \underline{z}(t), \underline{x}] \quad (13)$$

and is to be minimized subject to constraints in a similar form:

$$g_i(\underline{x}) = \max_t F_i[t, \underline{z}(t), \underline{x}] - \theta_i \leqslant 0 \quad i=1, 2, \ldots, p \quad (14)$$

The largest value for F_i permissible is θ_i. Additional constraints reflect limitations that may be necessary for each design variable:

$$x_{k\min} \leqslant x_k \leqslant x_{k\max} \quad (15)$$

The solution to this problem depends on replacing the max value functions with suitable integral functions so that concepts borrowed from optimal control can be applied. The optimization is performed by a method of generalized steepest descent, moving toward an optimum in small perturbations and integrating a set of adjoint equations at each step. The method reduces the number of numerical solutions required in an overall optimization; however, the optimization problem must be modified to obtain the integral functions. A new design variable x_{n+1} is added to the problem and a new constraint is formed:

$$g_o(\underline{x}) = \max_t F_o[t, \underline{z}(t), \underline{x}] - x_{n+1} \leqslant 0 \quad (16)$$

The objective in the optimization now becomes the minimization of x_{n+1}, which preserves the original goal, equation (13), provided g_o is treated just as the other g_i. Of two approaches for handling the maximum value constraints, the most effective was to define new integral constraints in an equality form so that

$$h_i(\underline{x}) = \int_0^T \langle g_i(\underline{x}) \rangle^2 \, dt = 0 \quad i = 0, 1, \ldots, p \quad (17)$$

where $\langle\alpha\rangle = 0$ if $\alpha \leqslant 0$ and $\langle\alpha\rangle = \alpha$ otherwise.

The computational speed of this approach has been compared to the straightforward application of nonlinear programming in isolator optimization [24]. An order of magnitude improvement in speed was noted. This optimization strategy has also been extended to structural design under dynamic loading [25]. In comparison with a more traditional approach to the structural optimization problem [26], computational speed was faster by a factor of five to ten.

Plates and Beams

The work of Van de Vegte and his associates in the design of absorbers for continuous structural elements has been extended since their original work on beams [23]. A similar approach has now been used to deal with plates [27, 28]; dynamic state variables are used to represent the vibration modes. Optimal control techniques are applied to optimize the transient response from arbitrary initial conditions. An integral objective function of quadratic form consists of a weighted sum of a state vector term and a control effort term. Rosenbrock's method was used for the required optimization search. A simply supported rectangular plate has been considered [27]; linear dampers are sized and positioned by the design procedure. Vibration control of a simply supported plate was also considered [28]; dynamic absorbers were used. Position, stiffness, and damping are selected for optimum behavior of the plate-absorber system; absorber mass is limited. Van de Vegte used the beam vibration problem [29] to develop a state equation model that includes damping. He abandoned the optimal control concepts [23, 27, 28], using instead an approach based on eigenvalue positioning. A search strategy combining Rosenbrock's and Powell's methods is used to locate the system eigenvalues as closely as possible to specified desired locations. The absorber parame-

ters are adjusted accordingly, and a solution to the eigenvalue problem is obtained at each stage. A dynamic absorber example is presented for sizing and positioning by the optimization procedure. Van de Vegte reports that this approach is more direct and efficient than the optimal control method.

THE FREQUENCY DOMAIN

Concepts previously used in the time domain have recently been applied in the frequency domain [30, 31]. Wang and Pilkey [30] have developed an approach to finding the best possible performance of a vibration absorber in a particular configuration. The forcing functions are sinusoidal; performance is based on the steady-state vibration of the system. Force generators replace isolator components, and the forces required for optimum performance are determined. Linear behavior of the force generators can be enforced by limiting the frequency of the generated force to that of the input frequency. Nonlinear behavior can be considered by not restricting the frequency of the generated force.

The equations of motion in this optimization are in the matrix form

$$M\ddot{\underline{z}} + C\dot{\underline{z}} + K\underline{z} + V\underline{u} = F\underline{f} \qquad (18)$$

The mass, damping, and stiffness matrices are M, C, and K respectively; $\underline{z}$ represents the displacements of the system masses. The forcing function $\underline{f}$ consists of forces of specified frequency and amplitude; $\underline{u}$ represents the absorber forces produced by force generators inserted at particular locations in the system. The V and F are matrices of constant coefficients. In the optimization, the objective function has the form

$$f(\underline{u}) = \mathrm{Max}(\psi_1, \psi_2, \ldots) \qquad (19)$$

where ψ_1, ψ_2,..., are components of the vector $\underline{\psi}$, which is a linear function of the accelerations, velocities, displacements, and forces:

$$\underline{\psi} = P_1\ddot{\underline{z}} + P_2\dot{\underline{z}} + P_3\underline{z} + P_4\underline{u} + P_5\underline{f} \qquad (20)$$

The P's are coefficient matrices. Minimization of any maximum acceleration, maximum relative displacement, or maximum force level can thus be carried out. General performance constraints can also be considered in a form similar to equations (19) and (20). Despite this general formulation, the optimization of the absorber forces $\underline{u}$ can be performed by linear programming. Each absorber force is considered to be in the form of a Fourier series; the design vector $\underline{x}$ consists of the m coefficients of the series terms that are to be optimized. Even a large linear programming problem can be solved efficiently. Linear absorbers can be considered by restricting the force generation frequencies to the particular frequencies of the forcing functions in $\underline{f}$. The technique can be applied to the design of passive absorber systems by selecting stiffness and damping components that best approximate the ideal absorber forces [31]. Related concepts have also been utilized for rotor balancing [32, 33].

Random Inputs

A number of interesting applications have appeared for isolation systems subjected to random inputs. These recent results consider both active isolation, which has the potential of achieving optimal control performance, and passive isolation systems, which can only approximate the ideal optimum. Vehicle systems are often considered in random input studies because of the natural occurrence of random profiles on the surfaces of road and tracks. Dahlberg [34-36] has presented a series of papers on optimization of a vehicle suspension system. He considered a simple one-degree-of-freedom suspension model [34]. Minimum mean value of the largest transmitted acceleration is obtained with limitations on relative displacement. A combination of interior and exterior penalty functions is applied. He extended the work to the traditional two-degree-of-freedom suspension system and considered best ride comfort subject to constraints on road holding and relative displacement [35]. Human sensitivity to vehicle seat acceleration is included, and the dependence of road input on vehicle speed is discussed. His most recent work [36] compares active and passive suspension performance on the two-degree-of-freedom system model. The effect of vehicle speed on the nature of the road input is emphasized; an active suspension is synthesized with parameters controlled by vehicle speed. In a comparison with a fixed spring and damper suspension, he found that the active suspension can make more effective use of available displacement space over the range of operating speeds.

The continuing work of Fujiwara and Murotso [37] is similar to that of Dahlberg. One- and two-degree-of-freedom systems are studied from the viewpoint of passenger comfort, and actual acceleration is filtered by the human sensitivity curve. Trade-off curves between comfort and relative displacement have been developed for a random road profile. Comparisons are presented between optimal control results and results using a spring and damper suspension to approximate the ideal system. Fujiwara and Murotsu have also studied the potential application of isolators optimized for random inputs [38]. Analog simulation was used to compare the performance of a system realizable by state variable feedback to the performance of an ideally optimized system.

The efforts of Hedrick and his colleagues are realistic [39, 40]. A strategy developed earlier has been used to study the optimum performance of vehicle suspensions on large, well-modeled systems. A fifteen-degree-of-freedom model of a railcar lateral suspension [39] has been optimized to maximize the vehicle speed at which hunting of the wheels begins. Constraints were placed on acceleration, suspension stroke, wheel forces, and steady-state suspension deflection on a curve. Design variables were included for primary and secondary suspension lateral stiffness and primary longitudinal stiffness. The method of Box was used in the search for a constrained optimum. An active lateral suspension to supplement a standard spring suspension was described [40]. On the basis of quadratic performance indices for vehicle motion and control effort, an improvement by a factor of five over a baseline suspension was noted for realistic railcar parameters. A power consumption of 2 kw was computed for the seven-degree-of-freedom model. The method of Hooke and Jeeves was used in the optimization.

CLOSING REMARKS

Research efforts over the last few years have produced progress in each area reviewed here. The current state of the art in efficiency of optimization strategies and the reduction of computer costs makes possible the solution of many realistic and practical design problems for shock and vibration isolator development. In future work we can expect further progress in efficient approaches for the optimal design of isolators and additional comparisons of various techniques. However, it seems that emphasis in the near future will be given to applications of optimal design strategies along two lines: the solution of problems in classical configurations and the solution of realistic problems for hardware application. Of course, work in these directions is well underway, but clearer definition of classical problems in the time and frequency domains with further attention to nonlinear components is expected. Optimal isolation systems in hardware and reports of experience in such applications, including active isolation systems, should be realized. Strategies for involving real-time computation in active isolation systems is also anticipated.

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BOOK REVIEWS

ENVIRONMENTAL NOISE POLLUTION

P.F. Cunniff
John Wiley & Sons, 1977

This text is intended for both technical or non-technical university students interested in noise pollution. Only a small fraction of its content will aid those who work in shock and vibration.

This reviewer particularly admires two features of Dr. Cunniff's text:

- Each technical point is followed by a numerical example showing exactly how formulas are applied in a typical computation

- Each chapter concludes with a summary of main points and a series of self-study review questions, problems (answers follow Chapter 12), and assignments.

The author lays a good foundation in his first chapter, commencing with Newton's F = MA. He reviews exponential notation, logarithms, antilogarithms, and basic algebra, obviously preparing the student for decibels. He concludes with a review of simple harmonic oscillation in pendulums and spring-mass systems, together with their acoustic analogs.

Chapter 2 deals with the speed of sound waves in air and introduces temperature effects, sound intensity, sound power, reflections, diffraction, absorption, and transmission. The summation of two or more sounds and the basic concepts of acoustic spectra are also covered.

Chapter 3 introduces the decibel concept, special rules for adding and subtracting decibels, and the separation of spectrum analysis into octaves and fractional octaves.

Chapter 4 introduces some basic sound measuring equipment used in environmental noise pollution work: microphones, sound level meters, weighting networks, calibrators, auxiliary equipment, and tape recorders. The chapter concludes with suggestions regarding use of these instruments.

Chapter 5 explains the control of wanted and unwanted sounds. Reverberation time (of a room), sound absorption, sound transmission loss, barriers, vibration isolators, and enclosures are covered.

The voice mechanism and ear anatomy and physiology are the subjects of Chapter 6. This reviewer had previously likened the cochlea to a frequency analyzer, but had not been aware of a piezoelectric effect in the hair cell/auditory nerve structure. Psychoacoustic data on hearing are related to A-, B-, C-, and D- weighting networks in sound level meters. Sones and phons are explained. Audiograms and demonstrations of temporary and permanent threshold shift are shown. Criteria for normal hearing are given.

Chapter 7 deals with the effects of noise on humans: hearing loss, speech interference, sleep and task interference, annoyance, and psychological effects.

Chapter 8 considers infrasounds below 16 Hz and ultrasounds above 20 000 Hz, such impulse noises as sonic booms, and the effects of noise on animals.

Chapter 9 reviews outdoor community noises, defining such terms as ambient noise, and introducing L_{10}, L_{50}, L_{90}, L_{eq}, L_{dn}, L_{NP} and related statistical indicators. The author carelessly uses the symbol f to represent fraction, having earlier used it in the standard manner to represent frequency.

Chapter 10 examines methods used for predicting the impact of transportation – aircraft, highway, rail, and recreational vehicles -- noise sources on humans.

Chapter 11 treats industrial noise, including both indoor and outdoor environments. CHABA and OSHA criteria are reviewed. Ear protection equipment is shown, along with noise dosimeters and histogram instruments.

Chapter 12 reviews federal, state, and local noise ordinances for the control of aircraft, surface, construction, and other noise radiation. Enforcement and penalty features and measurement procedures are examined.

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APPLIED ACOUSTICS

G. Porges
Halsted Press Div./John Wiley & Sons
New York, NY, 1977

This book provides the serious student with a thorough introduction to the elementary physics of room acoustics and noise control. Although similar in scope to dozens of books on this apparently hot topic that have been published over the past ten years, it is among the better ones because it has a single author with a consistent style and notation rather than the more typical edited collection of chapters by various authors. Included are chapters on wave equations, decibel notation, subjective response to sound, transmission through solids, sound absorption, room acoustics, barriers, and radiation from elementary sources. The author has an intimate familiarity with the acoustical characteristics of industrial and other common noise sources and describes them admirably. His detailed mathematical derivation of the spherical wave equation, and of normal and oblique transmission through solid panels, as well as the theory of the side branch resonator, also reflect his enthusiasm for pedagogy. All topics are based on steady-state acoustics; impulsive sound sources and transient response of structures or rooms are not discussed. Nor are industrial hearing loss regulations, community noise ordinances, and electronic sound reinforcement.

Although the author at one point dismisses phase differences between sound waves as generally unimportant, he later refers extensively to phase effects in a discussion of dipole sources, standing waves, Helmholtz resonators, and other topics. Phase is also critical to sound localization and beats between pure tones. The subject of auditorium acoustics is rather superficial, being limited to reverberation time, late echoes, standing waves, and focusing. No mention is made of the critical balance between early and later reflections in music spaces.

Coverage of other topics – membrane absorbers; the single-degree-of-freedom approach to vibration isolation; and relationships between sound power, intensity, and sound pressures and elementary transmission losses of walls, ducts, barriers, and enclosures – are clear and adequately detailed for the intended audience; e.g., students of environmental science and novice practitioners in noise control and room acoustics. The author appropriately calls attention to the typical disparity between the ideal diffuse sound field underlying the derivations of various basic acoustical formulas and the behavior of sound in the real world.

The book exhibits virtually flawless typography. The sparse graphics consist of very clear line drawings and one photograph. The appended log tables are somewhat superfluous in this age of the pocket calculator. The bibliography is thorough; however, the addition of annotations to appropriate sources for more detailed derivations and more extensive practical data among the references would have been useful. Although it provides no new information, the book neatly combines a variety of the more practical aspects of the classic, Kinsler and Frey's Fundamentals of Acoustics, as well as Noise Reduction (1960) edited by Beranek.

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STRUCTURAL MECHANICS SOFTWARE SERIES, Volume II

N. Perrone and W. Pilkey, Editors
University Press of Virginia, Charlottesville, 1978

The first two-thirds of the book contains user's guides for the following computer programs:

- SAP V, a general three-dimensional, linear, static and dynamic, finite element structural analysis program
- UCIN, a vehicle-occupant/crash-victim simulation model
- WHAMS, a program for the nonlinear, transient analysis of two-dimensional and axisymmetric three-dimensional structures and continua
- DISK, a program for static and dynamic response of discs, thick cylinders and thick spheres
- TWIST, a program for the static, stability, and dynamic response of torsional systems
- GRILL, a program for the static analysis of uniform grillages subjected to uniform, hydrostatic, and concentrated forces
- TABS 77, a program for three-dimensional static and dynamic analysis of multistory buildings

Each program is available on one or more computer networks: United Computing Systems, TYMSHARE, and University Computing Company. The book contains information on the availability of the programs, costs, documentation, and who to contact in case of trouble. This information is also given for programs described in Volume I of this series (PREMSAP, BOSOR, GIFTS, TOTAL, BEAM, BEAMSTRESS, and SHAFT).

The last third of the book surveys available programs that apply to the following areas: bridge rating systems, solid rocket nozzles, European finite element programs, cantilever retaining wall design, and pressure vessels. Information is given on program availability and documentation, as well as critical remarks and a comparison of the programs in each category.

The book will assist prospective users in deciding what program best suits their needs. The user's guides offer similar assistance to those who want to know how much trouble it will be to use the various programs, and what their specific capabilities and limitations are.

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SHORT COURSES

OCTOBER

DIAGNOSING ROTATING MACHINERY VIBRATION PROBLEMS

Dates: October 16-19, 1979
Place: Chicago, Illinois
Dates: October 30-November 2, 1979
Place: Houston, Texas
Objective: This seminar is designed to provide both an overview of machine vibration characteristics and diagnostic techniques and an in-depth examination of several solved machine vibration problems. Topics include the fundamental causes of machine vibration, determining component and structural frequencies, considerations for setting up a preventive maintenance program (such as machine failure characteristics, diagnostic technique effectiveness, thresholds, and criteria), and monitoring equipment operation and usage. Industrial consultants and university experts will be featured at each seminar to provide a detailed discussion of illustrative case histories and to suggest advanced diagnostic techniques to solve vibration problems.

Contact: John Sramek, GenRad, Inc., 2855 Bowers Ave, Santa Clara, CA 95051 - (408) 985-0700, Ext. 267.

SURFACE BLASTING

Dates: October 17-19, 1979
Place: Las Vegas, Nevada
Dates: October 31-November 2, 1979
Place: St. Louis, Missouri
Dates: November 14-16, 1979
Place: Tucson, Arizona
Dates: December 5-7, 1979
Place: Washington, D.C.
Objective: This is a field-oriented course on commercial surface blasting (quarries, open pits and construction). The course uses a variety of presentation techniques including movies, problem solving, question and answer sessions and special "hands-on" exercises. Topics to be covered are: commercial explosives in use today; detonation methods; rock breakage; blast design; blasting economics; and blasting and the neighbors.

Contact: E.I. du Pont de Nemours & Co. (Inc.), Room 35901, Wilmington, DE 19898 - (302) 774-6406.

NOISE CONTROL IN MACHINES

Dates: October 22-25, 1979
Place: The Pennsylvania State University
Objective: This seminar emphasizes the design of quiet equipment and noise reduction methods, such as mufflers and enclousres to meet current and projected federal regulations. All three aspects of machinery noise are covered: the nature and prediction of noise sources such as fans, compressors, jets, control valves, and vibrating surfaces; the propagation of sound through simple and complex walls and enclosures, as well as propagation in the out-of-doors; and the response of the receiver - the human being in the working or living environment in both physiological and psychological terms. The course also covers hands-on experience using the latest acoustical data acquisition and processing equipment.

Contact: David K. Furchner, The Pennsylvania State University, Radnor Campus - Continuing Education, 259 Radnor-Chester Rd., Radnor, PA 19087 - (215) 293-9860.

SIGNAL PROCESSING & SEMICONDUCTORS

Dates: October 22-26, 1979
Place: Sunnyvale, California
Objective: Applied Time Series Analysis, its implementation and applications will be the subject of an intensive learning session featuring leading instructors from academia and industry and highlighted by the addition of instructional laboratories and evening demonstrations of equipment by top manufacturers. Leading manufacturers of signal analyzers and semi-

conductor devices will participate with practical applications and discussions of course material as it applies to their equipment or devices.

Contact: Onstead & Associates Inc., 1107 Bartlett Creek Court, San Jose, CA 95120 - (408) 997-3415.

MACHINERY VIBRATIONS SEMINAR

Dates: October 23-25, 1979

Place: Mechanical Technology, Inc.
Latham, NY

Objective: To cover the basic aspects of rotor-bearing system dynamics. The course will provide a fundamental understanding of rotating machinery vibrations; an awareness of available tools and techniques for the analysis and diagnosis of rotor vibration problems; and an appreciation of how these techniques are applied to correct vibration problems. Technical personnel who will benefit most from this course are those concerned with the rotor dynamics evaluation of motors, pumps, turbines, compressors, gearing, shafting, couplings, and similar mechanical equipment. The attendee should possess an engineering degree with some understanding of mechanics of materials and vibration theory. Appropriate job functions include machinery designers; and plant, manufacturing, or service engineers.

Contact: Mr. Paul Babson, MTI, 968 Albany-Shaker Rd., Latham, NY 12110 - (518) 785-2371.

MACHINERY VIBRATION ANALYSIS

Dates: October 23-25, 1979

Place: Seattle, Washington

Objective: New techniques for measuring and analyzing vibration in rotating machinery will be covered. The seminar will feature hands-on time with the latest instrumentation used in advanced machinery maintenance. Machinery models and taped data from industrial process machinery will be used for realistic demonstrations of pinpointing the source of vibration and measuring its exact intensity and frequency. Also discussed will be hot alignment of coupled machines, field balancing of high-speed turbines, round-the-clock vibration monitoring systems, and managing vibration data by computer.

Contact: Bob Kiefer, Spectral Dynamics, P.O. Box 671, San Diego, CA 92112 - (714) 268-7192.

ROTATING MACHINERY VIBRATIONS COURSE

Dates: October 29-November 1, 1979

Place: Cherry Hill, New Jersey

Objective: This advanced course on rotating machinery vibrations will cover physical/mathematical modeling, mathematical computations, physical descriptions of vibration parameters, measuring, and analysis. Machinery vibrations control techniques will be discussed. Torsional vibration measurement, analysis, and control will be reviewed.

Contact: Dr. Ronald L. Eshleman, Vibration Institute, Suite 206, 101 West 55th St., Clarendon Hills, IL 60614 - (312) 654-2254/654-2053.

NOVEMBER

VIBRATION DAMPING

Dates: November 5-8, 1979

Place: University of Dayton Research Institute

Objective: Topics to be covered are: damping behavior of materials, response measurements of damped systems, surface damping treatments on vibrating members, discrete damping devices, special analytical problems, increasing linear viscoelastic material properties, damping of acoustic vibrations, selected case histories, problem solving sessions, and demonstration of digital fast fourier analyses.

Contact: Mrs. Audrey G. Sachs, University of Dayton Research Institute, Dayton, OH 45469 - (513) 229-2919.

DYNAMIC ANALYSIS WORKSHOP

Dates: November 5-9, 1979

Place: San Diego, California

Objective: This course will cover the latest techniques of analyzing noise and vibration in rotating machinery and power-driven structures. The workshop will cover both the theory and practical aspects of tracking down malfunctions and preventing failures caused by unbalance, misalignment, wear, oil whirl, etc. Included in the course will be demonstrations and practical, hands-on experience with the latest noise and vibration instrumentation; Real Time Analyzers, FFT Processors, Transfer Function Analyzers and Computer-Controlled Modal Analysis Sys-

tems. Actual case histories and specific machinery signatures will be discussed.

Contact: Bob Kiefer, Spectral Dynamics, P.O. Box 671, San Diego, CA 92112 - (714) 565-8211.

VIBRATION AND SHOCK SURVIVABILITY, TESTING, MEASUREMENT, ANALYSIS, AND CALIBRATION

Dates: November 5-9, 1979
Place: Arlington, Virginia
Dates: December 10-14, 1979
Place: Ling Electronics, Anaheim, California
Objective: Topics to be covered are resonance and fragility phenomena, and environmental vibration and shock measurement and analysis, also vibration and shock environmental testing to prove survivability. This course will concentrate upon equipments and techniques, rather than upon mathematics and theory.

Contact: Wayne Tustin, 22 East Los Olivos St., Santa Barbara, CA 93105 - (815) 682-7171.

THE APPLICATION OF VIBRATION MEASUREMENT AND ANALYSIS IN MACHINE MAINTENANCE

Dates: November 6-8, 1979
Place: New York, New York
Dates: November 13-15, 1979
Place: Dallas, Texas
Objective: These sessions are designed to give an understanding of the concept of using machinery vibration as a means of detecting wear in rotating parts, and of predicting machinery breakdowns. It will deal with the principles and methods of machine condition analysis and the economic benefits obtainable from condition monitoring. Fundamentals of vibration measurement and analysis are explained with particular reference to optimum choice of measurement parameter and techniques to avoid unnecessary errors and limitations in detection and diagnostic capability.

Contact: B&K Instruments, Inc., Bruel & Kjaer Precision Instruments, 5111 W. 164th St., Cleveland, OH 44142.

CONTROLLING THE EFFECTS OF PULSATIONS AND FLUID TRANSIENTS IN PIPING SYSTEMS

Dates: November 7-9, 1979
Place: San Antonio, Texas
Objective: The seminar will cover various means for preventing and controlling the detrimental effects of pulsations and fluid transients on piping, pumps, compressors, and other plant systems and equipment. Topics will include: pulsation generation mechanisms and their effects in plant piping and equipment; the SGA Compressor Installation Simulator (SGA Analog) and its applications; pulsation control and piping system design; mechanical response of plant components to pulsations and transient excitation; vibration control in piping systems; vibration-induced stress and meaningful stress criteria; transient fluid interaction of system components (flow instabilities, cavitation, flashing, piping effects on surge, etc.); effects and control of pulsations in flow measurement; and pulsation effects on the performance of compressor/pump installations.

Contact: Joe L. Gulinson, Southwest Research Institute, P.O. Drawer 28510, San Antonio, TX 78284 - (512) 684-5111, Ext. 2521.

THE 17TH ANNUAL RELIABILITY ENGINEERING AND MANAGEMENT INSTITUTE

Dates: November 12-16, 1979
Place: The University of Arizona
Objective: The following subjects will be covered: reliability engineering theory and practice, mechanical reliability prediction, reliability testing and demonstration, maintainability engineering, product liability, and reliability and maintainability management.

Contact: Dr. Dimitri Kececioglu, Aerospace and Mechanical Engineering Department, Aeronautical Engineering Building No. 16, University of Arizona, Tucson, AZ 85721 - (602) 626-2495/626-3901/626-3054.

DECEMBER

MACHINERY VIBRATION ANALYSIS

Dates: December 11-13, 1979
Place: New Orleans, Louisiana
Objective: The topics to be covered during this

course are: fundamentals of vibration; transducer concepts; machine protection systems; analyzing vibration to predict failures; balancing; alignment; case histories; improving your analysis capability; managing vibration data by computer; and dynamic analysis.

Contact: Bob Kiefer, Spectral Dynamics, P.O. Box 671, San Diego, CA 92112 - (714) 268-7100.

JANUARY

PROBABILISTIC AND STATISTICAL METHODS IN MECHANICAL AND STRUCTURAL DESIGN

Dates: January 7-11, 1980
Place: Tucson, Arizona
Objective: To provide practical information on engineering applications of probabilistic and statistical methods, and design under random vibration environments. Modern methods of structural and mechanical reliability analysis will be presented. Special emphasis will be given to fatigue and fracture reliability.

Contact: Dr. Paul H. Wirsching, College of Engineering, The University of Arizona, Tucson, AZ 85721 - (602) 626-3159/626-3054.

FINITE ELEMENT ANALYSIS

Dates: January 7-11, 1980
Place: Tucson, Arizona
Objective: The purpose of this course is to provide structural engineering practitioners with an understanding of the fundamental principles of finite element analysis, to describe applications of the method, and to present guidelines for the proper use of the method and interpretation of the results obtained through it. Emphasis will be placed upon the linear analysis of frameworks, plates, shells and solids; and dynamic analysis will also be treated.

Contact: Dr. Hussein Kamel, College of Engineering, The University of Arizona, Tucson, AZ 85721 - (602) 626-1650/626-3054.

FEBRUARY

FIXTURE DESIGN FOR VIBRATION AND SHOCK TESTING

Dates: February 11-15, 1980
Place: Santa Barbara, California
Dates: March 10-14, 1980
Place: St. Petersburg, Florida
Objective: The relative merits of various types of shakers and shock test machines are briefly considered, with most emphasis on electromagnetic shakers. The seminar will be devoted to practical and proven simplified design and fabrication techniques. An important area to be covered is that of evaluating a fixture once it is built.

Contact: Wayne Tustin, Tustin Institute of Technology, 22 East Los Olivos St., Santa Barbara, CA 93105 - (815) 682-7171.

FINITE ELEMENTS IN BIOMECHANICS

Dates: February 18-21, 1980
Place: Tucson, Arizona
Objective: As a forum for the exchange of ideas, for the definition of the state-of-the-art, and for the presentation of new research results in biomechanics.

Contact: Professor Bruce R. Simon, Dept. of Aerospace and Mechanical Engineering, College of Engineering, The University of Arizona, Tucson, AZ 85721 - (602) 626-3752/626-3054.

MARCH

MEASUREMENT SYSTEMS ENGINEERING

Dates: March 10-14, 1980
Place: Phoenix, Arizona

MEASUREMENT SYSTEMS DYNAMICS

Dates: March 17-21, 1980
Place: Phoenix, Arizona
Objective: Program emphasis is on how to increase productivity, cost-effectiveness and data-validity of data acquisition groups in the field and in the laboratory. Emphasis is also on electrical measurements of mechanical and thermal quantities.

Contact: Peter K. Stein, 5602 East Monte Rosa, Phoenix, AZ 85018 - (602) 945-4603/946-7333.

NEWS BRIEFS

news on current and Future Shock and Vibration activities and events

The Second International Symposium on Innovative Numerical Analysis in Applied Engineering Science

The Second International Symposium on Innovative Numerical Analysis in Applied Engineering Science will be held at the Ecole Polytechnique in Montreal, Canada, from June 16-20, 1980. Over 100 papers, covering a range of disciplines from solid mechanics (elasticity, fracture, visco-elasticity, elasto-plasticity) and structures to fluid mechanics (aerodynamics, free surface flow, acoustics) and fluid-structure interaction to diffusion, electromagnetic and biological problems, have been accepted. An equally wide range of numerical techniques (finite differences, finite elements, boundary integral equations, etc.) will be represented, with all papers published in proceedings to be available at the meeting. Keynote addresses are scheduled to be presented by O. Zienkiewicz of the U.K., J. Hess, G. Fix of the USA, J. Nedelec of France and M. Fortin of Canada.

Further information concerning the program and registration may be obtained from

Professor A.A. Lakis
Department of Mechanical Engineering
Ecole Polytechnique de Montreal
C.P. 6079, Station A
Montreal, Quebec, Canada, H3C 3A7

ABSTRACTS FROM THE CURRENT LITERATURE

Copies of articles abstracted in the DIGEST are not available from the SVIC or the Vibration Institute (except those generated by either organization). Inquiries should be directed to library resources. Government reports can be obtained from the National Technical Information Service, Springfield, VA 22151, by citing the AD-, PB-, or N- number. Doctoral dissertations are available from University Microfilms (UM), 313 N. Fir St., Ann Arbor, MI; U.S. Patents from the Commissioner of Patents, Washington, D.C. 20231. Addresses following the authors' names in the citation refer only to the first author. The list of periodicals scanned by this journal is printed in issues 1, 6, and 12.

ABSTRACT CONTENTS

ANALYSIS AND DESIGN

NONLINEAR ANALYSIS

79-1701
Harmonic Analysis of Dynamic Systems with Nonsymmetric Nonlinearities
P.-T.D. Spanos and W.D. Iwan
Dept. of Aerospace Engrg. & Engrg. Mechanics, The Univ. of Texas at Austin, TX 78712, J. Dyn. Syst., Meas. and Control, Trans. ASME, 101 (1), pp 31-36 (Mar 1979) 4 figs, 11 refs

Key Words: Harmonic analysis, Equivalent linearization equations, Multidegree of freedom systems

The generalized method of equivalent linearization is modified to be applicable for multi-degree-of-freedom dynamic systems with nonsymmetric nonlinearities subjected to harmonic monofrequency excitation. Applicable formulas are given for the construction of the equivalent linear systems related to a class of systems commonly encountered in engineering applications. As an example of its application, the proposed method is used to generate an approximate steady-state solution for a simple vehicle system. The accuracy of the approximate solutions is determined.

79-1702
The Modified Single Mode Method in the Investigations of the Resonant Vibrations of Non-Linear Systems
W. Szemplinska-Stupnicka
Inst. of Fundamental Technical Res., Polish Academy of Sciences, Swetokrzyska 21, 00-049 Warsaw, Poland, J. Sound Vib., 63 (4), pp 475-489 (Apr 22, 1979) 8 figs, 21 refs

Key Words: Nonlinear systems, Multidegree of freedom systems, Resonant frequencies

To study the effects of non-linearities on the resonant vibrations of multi-degree-of-freedom systems (lumped parameter or continuous ones) the modified single nonlinear mode method is presented and the results obtained are compared to those produced by the commonly used classical single mode method. As an illustrative example a three-degree-of-freedom system is examined; the resonance curves are determined by the modified method and by the classical single mode method, and the results are checked by the aid of the analog computer. New effects of the restoring force non-linearity are found, effects which are suppressed by the approximations of the classical single mode method.

79-1703
Multiple Scale Perturbation for Second-Order Non-Linear Differential Equations
R. Ling
Dept. of Mathematics, California State Univ., Los Angeles, CA 90032, Intl. J. Nonlin. Mech., 13 (5/6), pp 361-366 (1978) 4 refs

Key Words: Nonlinear theories, Perturbation theory

Asymptotic solutions of a class of second-order non-linear differential equations with variable coefficients are studied. For large values of the parameter, the differential equations are of the singular-perturbation type and appoximations are constructed by the generalized method of multiple scales.

NUMERICAL ANALYSIS

79-1704
Analysis of Massless Elastic Chains with Servo Controlled Joints
W.J. Book
Georgia Inst. of Tech., Atlanta, GA, ASME Paper No. 78-WA/DSC-34

Key Words: Lumped parameter method, Chains

The lumping approximation used frequently for dynamic analysis of distributed parameter systems is facilitated for a class of flexible systems by a technique developed here using 4 x 4 coordinate transformation matrices to account for the deflection of elastic elements under load. This technique is used to develop the linear equations of spatial motion for a system of two rigid masses connected by a chain with an arbitrary number of massless beams and controlled joint rotations.

STABILITY ANALYSIS

79-1705

Stability of Two-Level Control Schemes Subjected to Structural Perturbations

J.C. Geromel and J. Bernussou

Laboratoire d'Automatique et d'Analyse des Systemes du C.N.R.S., 7 Avenue du Colonel Roche, 31400 Toulouse, France, Intl. J. Control, 29 (2), pp 313-324 (Feb 1979) 2 figs, 13 refs

Key Words: Stability, Control systems, Perturbation theory

The paper deals with the problem of stability of large-scale interconnected systems with a two-level control subjected to structural perturbations. By means of Lyapunov vectors function, sufficient degrees of stability for each isolated subsystem are determined in order that the overall structure remains stable when perturbations occur between the two levels of control. Numerical features are discussed by means of two examples.

STATISTICAL METHODS

79-1706

A Density Equation for a Vibration System under Simultaneous Continuous and Discrete Stochastic Excitations (Eine Dichtegleichung f. Schwingungssysteme bei gleichzeitigen kontinuierlichen und diskreten stochastischen Erregungen)

A. Renger

108 Berlin, Zimm, Mohrenstr. 39, German Dem. Rep., Z. angew. Math. Mech., 59 (1), pp 1-13 (Jan 1979) 3 figs, 7 refs

(In German)

Key Words: Statistical analysis, Probability theory, Distribution functions, Vibrating structures

A partial integrodifferential equation is developed for the joint probability distribution of the response of vibration systems subjected simultaneously by Gaussian white noise and random impulses. This may be interpreted as a generalization of the Fokker-Planck equation to Markov processes without diffusion character. First investigations on the basis of this equation are demonstrated for the simple low-pass and a column subjected to shot noise.

MODELING

79-1707

A Mathematical Model for the Linear Dynamic Behavior of Two Phase Periodic Materials

H.D. McNiven and Y. Mengi

Univ. of California, Berkeley, CA 94720, Intl. J. Solids Struc., 15 (4), pp 271-280 (1979) 19 refs

Key Words: Mathematical models, Periodic structures, Walls, Masonry

In this study, a mathematical model is developed for two phase materials with the object of using it for predicting the response of masonry walls to dynamic inputs. The method employed here uses the theory of mixtures applied to a two phase material in which the phases reflect a periodic structure and in which each phase is linearly elastic. Employing the fundamental equations of the theory of mixtures, the governing equations of a linear approximate theory are established. The theory, valid for an arbitrary direction of motion, replaces the composite by a homogeneous, two phase, anisotropic, elastic solid. It accommodates the dispersive nature of the composite by means of an elastodynamic operator, which is introduced into the constitutive relations of the linear momentum interactions.

79-1708

Generation of Linear Dynamic Models from a Digital Nonlinear Simulation

C.J. Daniele and S.M. Krosel

NASA Lewis Research Ctr., Cleveland, OH, Rept. No. NASA-TP-1388; E-9490, 95 pp (Feb 1979)

N79-16796

Key Words: Mathematical models, Aircraft engines

The results and methodology used to derive linear models from a nonlinear simulation are presented. Both explicit and implicit formulations are addressed. Linear models are derived for the F 100 engine, and comparisons of transients are made with the nonlinear simulation. The problem of startup transients in the nonlinear simulation in making these comparisons is addressed. Also, reduction of the linear models is investigated using the modal and normal techniques. Reduced-order models of the F 100 are derived and compared with the full-state models.

DIGITAL SIMULATION

79-1709

Bond Graphs for Flexible Multibody Systems

D.L. Margolis and D.C. Karnopp

Dept. of Mech. Engrg., Univ. of California, Davis, CA 45616, J. Dyn. Syst., Meas. and Control, Trans. ASME, 101 (1), pp 50-57 (Mar 1979) 12 figs, 13 refs

Key Words: Simulation, Bond graph technique, Control equipment, Remote control, Flexural vibration

A method is presented for the analysis and simulation of the dynamic response of systems containing several long, flexible bodies driven by actuators at joints and attachment points. Applications include remote manipulators, cranes, and complex spacecraft. The geometric nonlinearities of rigid body dynamics are retained as well as small bending mode vibrations based upon linearized analysis.

PARAMETER IDENTIFICATION

79-1710

Modelling of Structural Behaviour from Frequency Response Data

A.P. Lincoln

Inst. of Sound and Vibration Research, Southampton Univ., Southampton, UK, Rept. No. ISVR-TR-83, 46 pp (Sept 1977)

N79-17276

Key Words: Parameter identification technique, Beams, Plates

A procedure for the identification of structural vibration parameters from frequency response data is presented and illustrated using examples taken from experimentally measured beam and plate inertance spectra. The derivation of lumped mass, stiffness and damping matrices from identified modal parameters is investigated.

79-1711

A Finite Element and Gradient Method for Identification of Parameters in a Class of Distributed Parameter Systems

H. Sehitoglu and R.E. Klein

Purdue Univ., West Lafayette, IN, ASME Paper No. 78-WA/DSC-29

Key Words: Parameter identification technique, Continuous parameter method, Finite element technique

A method is presented for the identification of parameters in distributed parameter systems governed by parabolic and hyperbolic partial differential equations. The method uses a finite element technique to reduce the system's governing equation into a set of ordinary differential equations. A suitable performance index is then minimized by using a gradient method. The method proposed requires measurement of the variable at a small number of points in the solution domain. The time derivative of the field variable is estimated by using derivative filter technique. The method can be used either on-line or off-line for identification purposes. Examples presented include the application of the method to one-dimensional wave and diffusion equations.

79-1712

An Approximation Approach to the Identification of Non-Linear Systems Based on Frequency-Response Measurements

E.M. Wysocki and W.J. Rugh

Electrical Engrg. Dept., The Johns Hopkins Univ., Baltimore, MD 21218, Intl. J. Control, 29 (1), pp 113-123 (Jan 1979) 9 figs, 5 refs

Sponsored by the Air Force Office of Sci. Res. Air Force Systems Command

Key Words: System identification technique, Frequency response method

A method for determining a model of the form S_M from measurements on the steady-state response of a non-linear system to co-sinusoidal inputs at a number of amplitudes and frequencies is presented. A harmonic analysis technique is used to choose linear subsystems in the model and then minimization of an integral square-error criterion to select certain free coefficients within these subsystems. The results are illustrated by application to a forced Duffing equation and a forced Van der Pol equation.

CRITERIA, STANDARDS, AND SPECIFICATIONS

(Also see No. 1777)

79-1713

Sound Measurement Standards for Surface Transportation Vehicles

R.K. Hillquist

P.O. Box 113, Milford, MI 48042, Noise Control Engr., 12 (3), pp 131-133 (May/June 1979) 4 tables, 3 refs

Key Words: Standards, Sound measurement, Motor vehicle noise, Rail transportation

Standards for the measurement of exterior and interior sound levels of highway and rail vehicles that have been developed and implemented throughout the world are summarized and work on new and revised standards is discussed.

SURVEYS AND BIBLIOGRAPHIES

79-1714

Reduction Methods for Problems of Vibration of Orthotropic Plates. Part I: Exact Methods

T. Sakata

Dept. of Mech. Engrg., Chubu Inst. of Tech., Kasugai, Nagoya-sub., 487 Japan, Shock Vib. Dig., 11 (5), pp 19-26 (May 1979) 6 figs, 24 refs

Key Words: Reviews, Plates, Orthotropism, Natural frequencies, Reduction methods

In this two-part article Part I describes three exact reduction methods. Part II describes a generalized reduction method. The reduction method is used to derive an approximate formula for estimating the natural frequency of an orthotropic plate. The natural frequencies of the isotropic plate are used. They are reduced without solving the differential equation governing free vibration of the orthotropic plate.

79-1715

High Temperature Damping of Dynamic Systems

D.I.G. Jones

Air Force Materials Lab., Wright-Patterson AFB, OH 45433, Shock Vib. Dig., 11 (5), pp 13-18 (May 1979) 4 figs, 21 refs

Key Words: Reviews, Vibration control, Vibration damping

This survey describes four major areas of high-temperature vibration control technology and progress since late 1976: measurement and characterization of damping behavior of enamels and glasses and high damping elastomers; effects of composition on damping behavior of glasses and enamels; practical design and application of damping treatments in industry and service; and further development of mechanical mechanisms of damping such as slip at interfaces.

79-1716

Some Recent Trends in Aircraft Flutter Research

P.N. Murthy

Indian Inst. of Tech., Kanpur, India, Shock Vib. Dig., 11 (5), pp 7-11 (May 1979) 1 fig, 10 refs

Key Words: Reviews, Aircraft, Flutter

This is a review of salient advances in the area of flutter since 1975. Trends in research and development are stressed. Only references considered relevant have been cited.

79-1717

Aircraft Sonic Boom: Studies on Aircraft Flight, Aircraft Design, and Measurement (A Bibliography with Abstracts)

G.E. Habercom, Jr.

National Technical Information Service, Springfield, VA, 197 pp (Apr 1979)

NTIS/PS-79/0264/6GA

Key Words: Bibliographies, Aircraft, Aerodynamic characteristics, Noise measurement, Sonic boom

The report discusses aerodynamic design of aircraft and wings, flight characteristics and maneuvers, supersonic transport characteristics, acoustic fields and noise measurement, Government policies and regulations, meteorological parameters, shock waves, and supersonic and hypersonic wind tunnel tests, along with other theoretical and general investigations. Structural and biological effects are documented in separate published searches. (This updated bibliography contains 188 abstracts, 7 of which are new entries to the previous edition.)

79-1718

Aircraft Sonic Boom: Effects on Buildings (A Bibliography with Abstracts)

G.E. Habercom, Jr.

National Technical Information Service, Springfield, VA, 82 pp (Apr 1979)

NTIS/PS-79/0265/3GA

Key Words: Bibliographies, Sonic boom, Buildings, Structural members

Research findings are cited on the effects of sonic booms on buildings, structural components, forms, windows, and walls. Test-house investigations are included, along with damage analysis and vibration response. Documentation is made on residential buildings. Other topics contained in the volume range from theory to failure analysis. Sonic boom propagation and effects on biological forms, including human responses, are cited in separate bibliographies (This updated bibliography contains 74 abstracts, 1 of which is a new entry to the previous edition.)

TUTORIAL

79-1719

Noise Control: An Engineering Discipline

E.L. Hixson

Dept. of Electrical Engrg., The Univ. of Texas at Austin, TX 78712, Noise Control Engr., 12 (3), pp 111-115 (May/June 1979) 1 fig, 2 tables, 13 refs

Key Words: Noise reduction

The scope of noise control engineering encompassing basic physical phenomena, human response, and economic constraint is discussed and technical preparation needed for dealing with these problems is suggested.

COMPUTER PROGRAMS

GENERAL

(Also see No. 1806)

79-1720

User's Guide to Computer Programs JET 5A and CIVM-JET 5B to Calculate the Large Elastic-Plastic Dynamically-Induced Deformations of Multilayer Partial and/or Complete Structural Rings

R.W.H. Wu, T.R. Stagliano, E.A. Witmer, and R.L. Spiker

Aeroelastic and Structures Research Lab., Massachusetts Inst. of Tech., Cambridge, MA, Rept. No. NASA-CR-159484, 381 pp (Nov 1978)

N79-18343

Key Words: Computer programs, Rings

These structural ring deflections lie essentially in one plane and are called two-dimensional (2-d). The structural rings may be complete or partial. These two types of rings may be either free or supported in various ways (pinned-fixed, locally clamped, elastic-foundation supported, mounting-bracket supported, etc.). The initial geometry of each ring may be circular or arbitrarily curved; uniform-thickness or variable-thickness rings are analyzed. Strain-hardening and strain-rate effects of initially-isotropic material are taken into account. An approximate analysis utilizing kinetic energy and momentum conservation relations is used to predict the after-impact velocities of each fragment and of the impact-affected region of the ring; this procedure is termed the collision-imparted velocity method (CIVM) and is used in the CIVM-JET 5B program. This imparted-velocity information is used in conjunction with a finite-element structural response computation code to predict the transient, large-deflection, elastic-plastic responses of the ring.

79-1721

HUFF, A One-Dimensional Hydrodynamics Code for Strong Shocks

D.J. Peters

School of Engrg., Air Force Inst. of Tech., Wright-Patterson AFB, OH, Rept. No. AFIT/GNE/PH/78D-9, 107 pp (Dec 1978)

AD-A063 481/6GA

Key Words: Nuclear explosions, Computer programs, Shock wave propagation

HUFF is a one-dimensional Lagrangian hydrodynamics computer code developed from the basic principles of mass, momentum, and energy conservation for strong shock propagation in a solid or gas. Results for two problems are presented which show the usefulness and limitations of the code and also serve as sample problems.

79-1722

An Algorithm and a Modular Subroutine for the CAP Model

I.S. Sandler and D. Rubin
Weidlinger Associates, 110 E. 59th St., New York, NY 10022, Intl. J. Numer. Anal. Methods Geomech., 3 (2), pp 173-186 (Apr 1979) 1 fig, 4 refs

Key Words: Computer programs, Ground shock, Nuclear explosion effects, Explosion effects

A cap model algorithm and the associated FORTRAN subroutine, CAP, are presented. The algorithm lends itself to a wide range of soil and rock cap models, and can easily be incorporated into most dynamic codes. The routine permits the user to obtain flexibility with respect to changes in functional forms and parameters with minor coding changes.

79-1723

A Wave-Envelope of Sound Propagation in Nonuniform Circular Ducts with Compressible Mean Flows

A.H. Nayfeh, J.E. Kaiser, and B.S. Shaker
Dept. of Engrg. Science & Mechanics, Virginia Polytechnic Inst. and State Univ., Blacksburg, VA, Rept. No. NASA-CR-3109, 69 pp (Mar 1979)
N79-18688

Key Words: Ducts, Variable cross section, Sound propagation, Computer programs

An acoustic theory is developed to determine the sound transmission and attenuation through an infinite, hard-walled or lined circular duct carrying compressible, sheared, mean flows and having a variable cross section. The theory is applicable to large as well as small axial variations, as long as the mean flow does not separate. A computer program was developed based on the wave-envelope analysis for general mean flows. Results are presented for the reflection and transmission coefficients as well as the acoustic pressure distributions for a number of conditions; both straight and variable area ducts with and without liners and mean flows from very low to high subsonic speeds are considered.

79-1724

Interactive Vehicle Dynamics and Ride Evaluation Package

F.B. Hoogterp
Army Tank-Automotive Res. and Dev. Command, Warren, MI, Rept. No. TARADCOM-12413, 54 pp (Nov 1978)
AD-A063 589/6GA

Key Words: Computer programs, Ground vehicles, Tracked vehicles, Ride dynamics

This report describes an integrated package for evaluating the dynamic effects of driving a vehicle across any described section of terrain. The model incorporated includes only the pitch and roll motions of the chassis or hull. The package is composed of four digital computer programs. Each program is designed to be run interactively and does not require that the user have any programming experience. The programs provide the capability to create vehicle data files, perform simulations, and specify the form and types of the output desired. A general description of the model structure, its capabilities and its limitations is included along with user instructions for running each program in the package.

79-1725

Dynamic Structural Analysis of Map Shelters

F.S. Wong and J. Isenberg
Weidlinger Associates, Menlo Park, CA, Rept. No. R-7834, DNA-4631Z, AD-E300 403, 207 pp (June 1978)
AD-A063 486/5GA

Key Words: Computer programs, Nuclear explosion effects, Protective shelters, Missiles

The study is part of the DNA C-6 Program to investigate the feasibility of one of the multiple aim point (MAP) basing concepts for the advanced M-X missile systems; namely, the shelter concept. Its objective is to identify requirements in the finite element analysis of the shelter response when the structure is subjected to nuclear environments, and to define an analysis methodology which can be followed in performing dynamic analyses of a shelter-like structure.

79-1726

General Aviation Airplane Structural Crashworthiness Programmers Manual

W.L. Labarge
Lockheed-California Co., Burbank, CA, Rept. No. FAA-RD-78-120; LR-23683, 210 pp (Dec 1978)
N79-16814

Key Words: Computer programs, Crash research (aircraft), Crashworthiness

One of a series of operational documents is presented for the KRASH digital computer program which predicts the structural response of vehicles to multidirectional crash environments. The manual is intended to facilitate bringing the program to an operational status on a user's computer system. Sections included are: program KRASH system requirements, input data deck, and the demonstration problem. Material within each section can be expanded or revised, as necessary, without affecting the other sections.

79-1727

General Purpose Computer Program for Interacting Supersonic Configurations: Programmer's Manual

W. Crill and B. Dale

Bell Aerospace Textron, Buffalo, NY, Rept. No. NASA-CR-145127, 218 pp (1977)

N79-18901

Key Words: Computer programs, Supersonic aircraft, Aircraft

The program ISCON (Interacting Supersonic Configuration) is described. The program is in support of the problem to generate a numerical procedure for determining the unsteady dynamic forces on interacting wings and tails in supersonic flow. Subroutines are presented along with the complete FORTRAN source listing.

79-1728

General Purpose Computer Program for Inter-Acting Supersonic Configurations. User's Manual

W. Crill and B. Dale

Bell Aerospace Textron, Buffalo, NY, Rept. No. NASA-CR-145128, 115 pp (1977)

N79-17798

Key Words: Computer programs, Aircraft wings, Airframes, Aerodynamic loads

The input data required to execute the computer program ISCON are described. The program generates a numerical procedure for the determination of unsteady aerodynamic forces on arbitrarily interacting wings and tails in supersonic flow. A velocity potential gradient method is used. Constant Mach number is assumed throughout the flow field. Lifting surfaces are represented by trapezoidal elements which can be generated automatically by the program. The wake field is represented by rectangular strip elements. The formulation is reviewed as well as input overview and input format. Instruction on how to use ISCON, a sample problem, and the restart feature are discussed. Program size limitations, computer program flow, and error messages are also included along with a description of the SS31 program used to compute the coefficients of surface spline.

79-1729

Aeroelastic Addition to NASTRAN

W.P. Rodden, R.L. Harder, and E.D. Bellinger

MacNeal-Schwendler Corp., Los Angeles, CA, Rept. No. NASA-CR-3094, 116 pp (Mar 1979)

N79-17812

Key Words: Computer programs, NASTRAN (computer programs), Flutter, Aeroelasticity

A description is given of the additions made to the NASTRAN program to allow analysis of aeroelastic phenomena. Several methods for flutter analysis are included, as well as the means for calculating random and gust response of aerodynamic surfaces and bodies under fluid flow. Doublet lattice, mach box, and piston theory aerodynamics are all incorporated. Interference between bodies and surfaces is accounted for, and several basic illustrative examples are presented.

79-1730

DAFT: A Dynamic Analysis Computer Program

Arup (Ove) & Partners, London, UK, 10 pp (1978)

N79-18618

Key Words: Computer programs, Dynamic structural analysis, Fourier analysis, Interaction: soil-structure, Wind-induced excitation, Earthquake response

This dynamic analysis program was developed under the sponsorship of the Department of Energy. It is called DAFT (Dynamic Analysis using Fourier Transforms). It is a dynamic analysis tool which can consider 2D or 3D models of structures on land or in water. The structures can be situated on various types of support, and can be subjected to various types of dynamic loading such as earthquakes and wave loadings. One of the major features of the program is that it can analyze soil-structure systems allowing for radiation damping in the soil; this phenomenon is handled using a frequency-dependent formulation of the soil treated as a half-space. Fourier transforms are involved.

ENVIRONMENTS

ACOUSTIC

(Also see Nos. 1713, 1718, 1745, 1821)

79-1731

Approximate Formula for Second-Order Rayleigh Scattering From N Acoustical Scatterers

M.J. Lavan

2719 Imperial Drive S.E., Huntsville, AL 35801, J. Sound Vib., 64 (1), pp 57-61 (May 8, 1979) 2 figs, 5 refs

Key Words: Acoustic scattering

A model of second-order multiple scattering from N Rayleigh acoustical scatterers distributed at random throughout a volume V is analyzed, physically motivated approximations being used. The result is a simple expression for the angular distribution of the total second-order Rayleigh scattered flux that is analogous to the usual formula for first-order scattering from N independent scatterers.

79-1732

The Construction of Solutions to Acoustic Scattering Problems in a Spherically Stratified Medium. II

D. Colton and R. Kress

Dept. of Mathematics, Univ. of Delaware, Newark, DE, Quart. J. Mech. Appl. Math., 32 (1), pp 53-71 (Feb 1979) 4 figs, 6 refs

Key Words: Acoustic scattering, Layered materials

This paper is a continuation of previous work on the use of integral operators in solving scattering problems in a spherically stratified medium. In the present work a transmission problem for the reduced wave equation in a spherically stratified medium is considered. Based on a new representation for solutions of the reduced wave equation defined in interior domains, the first Born approximation for the scattered field is derived and how methods can also be used to obtain approximations for larger values of the frequency where the Born approximation may no longer be valid are indicated.

79-1733

Arrival Times of Scattered Ultrasonic Signals from a Solid Inclusion in an Elastic Material

D.J. Rhodes and W. Sachse

Dept. of Theoretical and Appl. Mechanics, Cornell Univ., Ithaca, NY 14853, J. Acoust. Soc. Amer., 65 (5), pp 1116-1120 (May 1979) 3 figs, 2 tables, 10 refs

Key Words: Acoustic scattering, Discontinuity-containing media

Measurements are reported of the arrival times of broadband ultrasonic pulses scattered by a circular, cylindrical, solid inclusion imbedded in a matrix whose longitudinal wave speed is lower than that of the scatterer. The matrix materials are water, polyester, and brass; and the inclusion materials are copper, quartz, stainless steel, and tungsten.

79-1734

Nonspecular Acoustic Backscattering from Finite Plates

M.L. Rumerman

David W. Taylor Naval Ship Res. and Dev. Center, Bethesda, MD 20084, J. Acoust. Soc. Amer., 65 (5), pp 1121-1126 (May 1979) 1 table, 6 refs

Key Words: Plates, Acoustic scattering

A method of calculating levels of farfield nonspecular acoustic backscattering from finite plates at frequencies above coincidence, due to scattering of flexural waves from the edges of the plate, is presented. For water-load steel plates at frequency-thickness products above 20 kHz-in., the flexural vibration can be adequately represented by the edge component and the supersonic wave. The amplitudes of these components are found by satisfying the boundary conditions, and the reradiated sound levels can then be calculated. The Timoshenko-Mindlin plate model is used, and comparison of calculated results with experimental results shows good agreement.

79-1735

Acoustic Scattering From an Elliptic Body

L. Maestrello and A. Bayliss

NASA Langley Research Ctr., Hampton, VA, Rept. No. NASA-TM-78815, 14 pp (Dec 1978)
N79-17657

Key Words: Acoustic scattering, Numerical analysis

The interaction of aerodynamic noise with a fuselage shaped body is considered. The first problem is the effect of scattering of an acoustic source by a body at rest. A numerical technique is presented which permits the computation of this scattering for frequencies of aeroacoustic interest. A parallel experiment is described which confirms the results of the computations. A numerical study of varying the geometry of the scattering is presented. The second problem is to simulate the effect of forward motion on the mean velocity and static pressure profiles in the wake of such a body with a jet exiting from it. Experimental results are presented and a similarity law is given.

79-1736

Underwater Acoustic Imaging

J.L. Sutton

Naval Ocean Systems Center, San Diego, CA 92152, Proc. of IEEE, 67 (4), pp 554-566 (Apr 1979) 18 figs, 10 refs

Key Words: Acoustic techniques, Underwater sound, Acoustic detectors, Acoustic imaging

In this report, the general characteristics of underwater acoustic imaging are presented. Three basic techniques of acoustic imaging that are appropriate for underwater imaging are discussed (focused, beam-formed, and holographic) and examples of each of them are described. The limitations and promise for the future in underwater acoustic imaging are explored.

79-1737

Signal Processing in Acoustic Imaging

P.N. Keating, T. Sawatari, and G. Zilinskas

Bendix Research Labs., Southfield, MI 48076, Proc. of IEEE, 67 (4), pp 496-510 (Apr 1979) 16 figs, 103 refs

Key Words: Acoustic techniques, Acoustic imaging, Signal processing techniques

A review of signal processing methods which can be used to improve the effectiveness of systems designed for acoustic imaging and bearing estimation is presented. Topics covered include signal processing for increased resolution; the processing of stochastic acoustic signals; image processing, enhancement; and pattern recognition. The discussion of resolution processing includes lateral resolution improvement by both superresolution techniques and aperture synthesis, and improvement of both range and Doppler resolution. The stochastic signal-processing section addresses adaptive processing, as well as methods of imaging in the case of incoherent, noisy signals.

79-1738

Ultrasonic Imaging Using Arrays

A. Macovski

Electrical Engrg. & Radiology Dept., Stanford Univ., Stanford, CA 94305, Proc. of IEEE, 67 (4), pp 484-495 (Apr 1979) 11 figs, 27 refs

Key Words: Ultrasonic techniques, Acoustic techniques

An analysis is presented of the two general types of arrays -- the direct imaging array and the phased array. These are analyzed over three levels of approximation: geometric optics, steady-state sinusoidal diffraction, and wide-band diffraction. Systems are studied which provide electronic deflection and focusing. In addition, systems are considered which exhibit high resolution in both lateral dimensions.

79-1739

Seismic Imaging by Holography

G.L. Fitzpatrick

Seismic Acoustics Lab., Univ. of Houston, 4800 Calhoun Blvd., Houston, TX 77004, Proc. of IEEE, 67 (4), pp 536-553 (Apr 1979) 18 figs, 27 refs

Key Words: Holographic techniques, Seismic response

This paper reports on the applications of an imaging technique, namely holography, with particular emphasis on Fourier transform holography. A variety of laboratory, field, and computer experiments are described together with several anticipated practical applications.

79-1740

Nonlinear Acoustoelasticity of Isotropic Elastic Materials

T. Toluoka

Dept. of Aeronautical Engrg., Kyoto Univ., Kyoto, Japan, J. Acoust. Soc. Amer., 65 (5), pp 1134-1139 (May 1979) 1 table, 16 refs

Key Words: Nonlinear theories, Elastic waves, Sound propagation, Elastic media

In this paper the propagation velocities and the stress-acoustical laws are obtained in the linear and the nonlinear forms for the general isotropic elastic materials.

79-1741

Investigation of Coannular Nozzles with Conventional and Inverted Velocity Profiles. Final Report, Sept 1976 - Apr 1978

B.H. Goethert, J.R. Maus, W.A. Dunnill, I. Dathe, S. Venkitarama, and L. Bates

Tennessee Univ. Space Inst., Tullahoma, TN, Rept. No. FAA-RD-78-32, 140 pp (Apr 1978)

N79-17661

Key Words: Jet noise, Noise measurement

The noise characteristics of the exhaust jets from coannular nozzles with conventional and inverted velocity profiles are investigated. Experiments are made on a series of coannular nozzles of equal primary and secondary areas. The majority of acoustic tests are carried out holding either the total thrust or the total mass flow constant while varying the rates of secondary velocity to primary velocity. A limited number of tests are also made simulating the takeoff, cutback and approach conditions of the JT8D engine and corresponding inverted conditions.

SEISMIC

(Also see Nos. 1750, 1751, 1762, 1851, 1852, 1853, 1856, 1857, 1858, 1860, 1861, 1862)

79-1742

Analysis of Three-Dimensional Strong Ground Motions Along Principal Axes, San Fernando Earthquake

T. Kubo and J. Penzien

Univ. of Tokyo, Tokyo, Japan, Intl. J. Earthquake Engr. Struc. Dynam., 7 (3), pp 265-278 (May/June 1979) 8 figs, 3 tables, 18 refs

Key Words: Ground motion, Earthquakes

An orthogonal set of principal axes is defined for earthquake ground motions. These principal axes are obtained such that the corresponding variances of motion have maximum, minimum and intermediate values and the covariances equal zero. Since real earthquake accelerograms are assumed to be reasonably well represented by Gaussian random processes, the three components of motion along the principal axes are statistically independent of each other. Using these principal axes and applying the moving-window technique to the ground accelerograms recorded during the San Fernando earthquake of 9 February 1971, time-dependent characteristics of three-dimensional ground motions along principal axes are determined.

SHOCK

(Also see Nos. 1721, 1722, 1725, 1727, 1848, 1849, 1880)

79-1743

The Determination of Shock Loads at Fracture of High Speed Internal Grinding Wheel (Ermittlung stossförmiger Belastungen beim Bersten schnell rotierender Innenschleifkörper)

G. Clement

Forschungszentrum des Werkzeugmaschinenbaus im VEB Werkzeugmaschinenkombinat, "Fritz Heckert" Karl-Marx-Stadt, German Dem. Rep., Maschinenbautechnik, 28 (4), pp 148-151 (Apr 1979) 6 figs, 6 refs

(In German)

Key Words: Impact tests, Energy absorption, Grinding machinery, Fracture properties, Protective shields

An experimental, computer-aided technique is presented for the determination of kinetic forces of fragments broken off the fractured internal grinding wheel and impacting on its protective hood. From the measured and calculated initial impact duration, the damped vibrations of impacted locations are calculated. Design characteristics for vibrating protective hoods and their mountings are proposed.

79-1744

On One-Dimensional Shock Waves

V.N. Bogayevsky and A.Y. Povzner

Institut of Physics of the Earth, The Academy of Sciences of the USSR, Intl. J. Nonlin. Mech., 13 (5/6), pp 337-349 (1978) 4 refs

Key Words: Shock wave propagation

In this paper uniform asymptotic expansions for the solutions of differential equations are obtained in the domain containing a shock wave. The results are applicable to one-dimensional problems in gas dynamics with low viscosity and heat-conductivity.

79-1745

Subjective Loudness of Simulated Quarry Blast Waves, with Implications for the Transition from Impulsive to Continuous Sound

A. Niedzwiecki and H.S. Ribner
Inst. for Aerospace Studies, Univ. of Toronto, 4925 Dufferin St., Downsview, Ontario, Canada M3H 5T6,
J. Acoust. Soc. Amer., 65 (5), pp 1212-1216 (May 1979) 6 figs, 1 table, 16 refs

Key Words: Mines (excavations), Noise generation, Simulation, Shock waves

The tradeoff between amplitude and duration for equal loudness is explored for idealized quarry blast waves. An extended low-frequency response loudspeaker-driven simulation booth is employed with computer-generated input test signals. The applicability of the method has been demonstrated for other types of transient sounds than the N wave; and the extension of the method tentatively appears to bridge the range between impulsive and continuous sounds of similar spectral content.

PHENOMENOLOGY

COMPOSITE

(Also see Nos. 1732, 1819)

79-1746

Mixture Theory for Longitudinal Wave Propagation in Unidirectional Composites with Cylindrical Fibers of Arbitrary Cross Section - I

H. Murakami, A. Maewal, and G.A. Hegemier
Univ. of California, San Diego, La Jolla, CA 92093,
Intl. J. Solids Struc., 15 (4), pp 325-334 (1979) 1 fig, 15 refs

Key Words: Composite materials, Fiber composites, Wave propagation, Boundary value problems

A binary mixture theory is developed for propagation of longitudinal waves in a unidirectional, fibrous composite containing a two-dimensional periodic array of cylindrical fibers of arbitrary cross section. The case considered concerns a class of problems for which the waves propagate in the direction of the fiber axis. Model construction is based upon an asymptotic scheme wherein the signal wavelength is assumed to be large compared to composite micro-dimension.

79-1747

Mixture Theory for Longitudinal Wave Propagation in Unidirectional Composites with Cylindrical Fibers of Arbitrary Cross Section - II

H. Murakami, A. Maewal, and G.A. Hegemier
Dept. of Appl. Mechanics and Engrg. Sciences, Univ. of California, San Diego, La Jolla, CA 92093,
Intl. J. Solids Struc., 15 (4), pp 335-357 (1979) 19 figs, 1 table, 4 refs

Key Words: Composite materials, Fiber composites, Wave propagation, Boundary value problems, Finite element technique, Variational methods

A variational principle-based finite element procedure is described for solution of microstructure boundary value problems derived in the first part of the paper in order to calculate the mixture properties that are required in the mixture theory formulated therein. Numerical analyses are carried out for several microstructural geometries of practical interest. The theory is used to study dispersion of longitudinal waves in composites with several microstructural geometries of practical interest.

79-1748

Propagation of Transient Waves in Elastic Laminated Composites

H.D. McNiven and Y. Mengi
Univ. of California, Berkeley, CA 94720,
Intl. J. Solids Struc., 15 (4), pp 303-318 (1979) 9 figs, 4 tables, 7 refs

Key Words: Composite structures, Wave propagation, Transient excitation, Walls, Masonry

The paper is devoted to the appraisal of a model material which can be used to replace one constructed of alternate plane layers. The material is homogeneous, anisotropically elastic and is dispersive. The purpose of the model is to study the dynamic response of masonry walls. The equations governing the model consist of constitutive equations and equations of linear momentum. The theory is constructed using the theory of mixtures and dispersion is accommodated by means of elastodynamic operators introduced into the equations of linear momentum. The theory contains nineteen constants. The derivation of the governing equations and equations relating the model constants to those of the prototype are presented in earlier papers. In this paper the model is appraised by comparing the responses predicted by the model for a transient input with those observed experimentally.

DAMPING

(Also see Nos. 1819, 1836)

79-1749

The Maximax Response of Discrete Multi-Degree-of-Freedom Systems

N.A.N. Youssef and N. Popplewell

Dept. of Mech. Engrg., Univ. of Manitoba, Winnipeg, Canada, J. Sound Vib., 64 (1), pp 1-15 (May 8, 1979) 10 figs, 15 refs

Key Words: Tuned dampers

Estimates of the maximax displacements of multi-, rather than single-degree-of-freedom systems to incompletely described loads are shown.

79-1750

The Effective Period and Damping of a Class of Hysteretic Structures

W.D. Iwan and N.C. Gates

California Inst. of Tech., Pasadena, CA, Intl. J. Earthquake Engr. Struc. Dynam., 7 (3), pp 199-211 (May/June 1979) 8 figs, 2 tables, 16 refs

Key Words: Earthquake response, Hysteretic damping

This paper presents the results of a numerical investigation in which the maximum response of six hysteretic systems is calculated for an ensemble of twelve earthquakes. Inelastic response spectra are constructed for a range of response ductility. An effective linear period and damping are calculated for each system and ductility by determining those parameters which minimize an RMS response spectrum error. Conclusions are presented concerning the effects of deterioration, stiffness degradation, cracking and ductility on the effective linear system parameters.

79-1751

Estimating Earthquake Response of Simple Hysteretic Structures

W.D. Iwan and N.C. Gates

California Inst. of Tech., Pasadena, CA, ASCE J. Engr. Mech. Div., 105 (EM3), pp 391-405 (June 1979) 5 figs, 3 tables, 12 refs

Key Words: Seismic excitation, Hysteretic damping

This paper examines various methods for defining effective linear systems for the earthquake response analysis of simple hysteretic structures. A broad class of approximate methods is considered including: harmonic equivalent linearization, resonant amplitude matching, dynamic mass, constant critical damping, geometric stiffness, geometric energy, stationary random equivalent linearization, and average period and damping. A technique for estimating the accuracy of different approximate methods is presented. A new linearization scheme that may be applied to both degrading and nondegrading hysteretic systems is proposed.

79-1752

An Off-Design Correlation of Part Span Damper Losses Through Transonic Axial Fan Rotors

W.B. Roberts, J.E. Crouse, and D. Sandercock

Nielsen Engrg. and Research, Inc., Mountain View, CA, ASME Paper No. 79-GT-6

Key Words: Fans, Rotors, Dampers

A correlation is proposed that calculates the off-design performance of part-span dampers. This method is based on rotor performance where the damper was located near the mid-chord and the blade shape and thickness were not modified to take into account the increase in blockage due to the damper.

79-1753
Dynamical Force Measurement to Check the Dampers of Telescopes (Dynamische Kraftmessung bei der Prüfung von Teleskopstossdämpfern)
E. Nier
Measurement of Force and Mass, Intl. Conf. of the Intern. Messtechn. Konfoder., Braunschweig, 13-15 Sept 1978, VDI Bericht. 312, VDI Verlag GmbH: Düsseldorf 1978, pp 129-133, 4 figs, 3 refs
(In German)

Key Words: Dynamic tests, Shock absorbers, Damping values

The present paper describes a force measuring system applied to final testing of series-produced telescopic shock absorbers. The damping force is continuously measured both in the tensile force and the compressive force direction. By applying nominal value, actual value comparisons, final testing procedures can be considerably facilitated.

ELASTIC
(Also see No. 1748)

79-1754
The Influence of Porosity on Vibrations of Elastic Solids
A.I. Beltzer
Holon Ctr. for Tech. Education, P.O.B. 305, Holon, Israel, J. Sound Vib., 63 (4), pp 491-498 (Apr 22, 1979) 4 figs, 23 refs

Key Words: Elastic materials, Porous materials, Vibration response, Flexural vibration, Beams

A general dissipative model is presented to evaluate the influence of small randomly distributed pores on the dynamic response of elastic structures. The numerical results are given for transverse wave propagation and for vibrations of a beam. It is shown that analysis of vibrations of elastic solids containing random porosity can be carried out by the methods of viscoelasticity.

79-1755
Dynamic Variational Principles for Discontinuous Elastic Fields
M. Cengiz Dokmeci
Univ. of California, Berkeley, CA, J. Ship Res., 23 (2), pp 115-122 (June 1979) 67 refs

Key Words: Elastodynamic response, Variational methods

Various forms of variational principles are derived for the three-dimensional theory of elastodynamics. The generalized forms of certain types of earlier variational principles are systematically constructed using a basic principle of physics. The variational principles derived herein are shown to generate, as the appropriate Euler equations, the complete set of the governing equations of linear elastodynamics, that is, the stress equations of motion, the strain displacement relations, the mixed natural boundary conditions, the constitutive equations, the natural initial conditions, and the jump conditions. Generalized variational principles are established for the nonlinear theory of elastodynamics, for the incremental motions in linear elasticity, and for an elastic Cosserat continuum.

FATIGUE
(Also see Nos. 1799, 1803)

79-1756
Boundary and Initial Conditions for Matrices Used for Load Sequence Generation
H.G. Koebler and R. Fischer
Royal Aircraft Establishment, Farnborough, UK, Rept. No. RAE-Lib-Trans-1959, 12 pp (Dec 9, 1977)
Engl. transl. of Conf. Paper from Lab. f. Betriebsfestigkeit, Darmstadt, West Germany
N79-18344

Key Words: Fatigue testing

The computerized synthesis of a sequence of peaks and troughs from a matrix-scheme is a suitable method in order to generate pseudo-random load-time histories for fatigue testing. The handling of a transition matrix as necessary to generate a sequence of peaks and troughs is done in a manner of lotting. There are two different principles to note: the lotting without or with restoration of lots. In practice, sequences of pseudo-random numbers are used. In order to assure the complete realization of the transition frequencies required and its reliable reproducibility some particularities have to be observed, which are illustrated by elementary examples.

79-1757

The Effect of Vibration on the Mechanical Properties of Structural Steel (Einfluss der Schwingungsbeanspruchung auf die mechanischen Eigenschaften von Baustähalen)

I. Havas and E. Czoboly

Technische Universität Budapest, Hungary, Maschinenbautechnik, 28 (4), pp 173-174 (Apr 1979) 4 figs, 1 ref

(In German)

Key Words: Steel, Fatigue (materials), Fracture properties

During a cyclic excitation of indented samples of St 52 steel, vibration excitation above the fatigue strength of the samples significantly reduces their specific energy of fracture. With an increasing prestressing, the resistance of material to fracture is reduced. These results are of great importance in the size determination of vibrating structures with stress concentrations.

FLUID

(Also see Nos. 1801, 1864)

79-1758

Gust Load Estimation Using a Simplified Power Spectral Technique. Final Report, Apr 1977-Apr 1978

G. Williamson

Aeronautical Research Associates of Princeton, Inc., NJ, Rept. No. ARAP-362; FAA-RD-78-118, 26 pp (Oct 1978)

N79-17870

Key Words: Power spectra, Wind-induced excitation, Turbulence

A one-degree-of-freedom power spectral technique for estimating gust loads on aerodynamic surfaces produced by atmospheric turbulence is presented. A procedural flow chart to guide the designer in the use of this technique and sample calculations are included.

79-1759

Quasi-Periodic Structure of a Turbulent Jet

L. Maestrello and Y.-T. Fung

NASA Langley Research Ctr., Hampton, VA 23665, J. Sound Vib., 64 (1), pp 107-122 (May 8, 1979) 18 figs, 12 refs

Key Words: Fluid-induced excitation, Sound pressures, Sound measurement, Statistical analysis

The instantaneous near field pressure fluctuations of an axisymmetric subsonic jet are measured by using a longitudinal and an azimuthal microphone array in order to qualitatively determine the behaviors of the quasi-periodic structure within the flow. Statistical analysis is used to explain the characteristic of the pressure signals. In addition to the information obtained by forming the power spectral density, auto- and cross-correlation functions, two types of signals are extracted through a conditional probability analysis to represent the quasi-periodic and the random fine structures within the turbulent jet.

79-1760

Attenuation of Sound in a Low Mach Number Nozzle Flow

M.S. Howe

Bolt Beranek and Newman, Inc., Cambridge, MA, Rept. No. NASA-CR-3086, 46 pp (Feb 1979)

N79-17660

Key Words: Sound attenuation, Fluid-induced excitation

The energy conversion mechanisms which govern the emission of low frequency sound from an axisymmetric jet pipe of arbitrary nozzle contraction ratio in the case of low Mach number nozzle flow are discussed. The energy of the incident sound which flows through the nozzle is used to maintain two distinct characteristic disturbances in the exterior fluid. First, there is the emitted radiation which has the directivity equivalent to that of a monopole-dipole combination. Second, essentially incompressible vortex waves are induced on the jet by vortex shedding from the lip of the nozzle and may involve the excitation of instability modes. Two linearized analytical models are examined to determine the partition of the emitted energy between the radiation field and the vortex waves. One of these is an exact linear theory in which the jet boundary is treated as a vortex sheet. The second model assumes that the width of the mean shear layer of the jet cannot be neglected. The results are discussed with reference to recent nozzle attenuation measurements.

79-1761

Substructure Variational Analysis of the Vibrations of Coupled Fluid-Structure Systems. Finite Element Results

H. Morand and R. Ohayon

Office National d'Etudes et de Recherches Aerospatiales (ONERA), Chatillon, France, Intl. J. Numer. Methods Engr., 14 (5), pp 741-755 (1979) 2 figs, 2 tables, 28 refs

Key Words: Fluid-filled containers, Interaction: structure-fluid, Coupled response, Component mode synthesis, Finite element technique

The finite element method is used for the computation of the variational modes of the system composed of an elastic tank partially filled with a compressible liquid. A direct approach is proposed based on a three field mixed variational formulation, and a variational modal interaction scheme is also proposed allowing the use of the acoustic eigenmodes of the liquid in a rigid motionless enclosure and the hydroelastic modes of the enclosure.

79-1762

Earthquake Sloshing in Annular and Cylindrical Tanks

M. Aslam, W.G. Godden, and D.T. Scalise

Bechtel Corp., San Francisco, CA, ASCE J. Engr. Mech. Div., 105 (EM3), pp 371-389 (June 1979) 12 figs, 2 tables, 16 refs

Key Words: Cylindrical bodies, Tanks (containers), Sloshing, Seismic excitation

The sloshing response of water in annular as well as in cylindrical tanks under horizontal earthquake ground motions is studied. A linear analysis, developed for the general annular tank problem, is based on potential flow theory. The predicted values of natural frequencies, surface displacements, and dynamic pressures are compared with measured data from shaking table tests.

79-1763

The Influence of Sweep on Aerodynamic Loading of an Oscillating NACA 0012 Airfoil. Volume 2: Data Report

A.O. St. Hilaire and F.O. Carta

United Technologies Corp., East Hartford, CT, Rept. No. NASA-CR-145350, 388 pp (Feb 1979)
N79-17802

Key Words: Airfoils, Aerodynamic loads

The effect of sweep on the dynamic response of the NACA 0012 airfoil is investigated. Unsteady chordwise distributed pressure data are obtained from a tunnel spanning wing equipped with 21 single surface transducers (13 on the suction side and 8 on the pressure side of the airfoil). A compilation of all the response data obtained during the test program is presented. These data are in the form of normal force, chord force, lift force, pressure drag, and moment hysteresis loops derived from chordwise integrations of the unsteady pressure distributions.

79-1764

Representation of the Effect of Winds in the Equations of Motion (Berucksichtigung des Windeinflusses in den flugmechanischen Gleichungen)

P. Krauspe and J. Klenner

Technisches Universität Braunschweig, Rebenring 18, 3300 Braunschweig, Germany, Z. Flugwiss, 3 (1), pp 23-28 (1979) 4 figs, 5 tables, 9 refs
(In German)

Key Words: Flight vehicles, Wind induced excitation, Equations of motion

A suggestion for the nomenclature of a set of direct Euler angles between the aerodynamic and the flight path fixed axis systems is introduced. The exact equations to determine these angles are given as well as practicable approximate solutions. The accuracy of the approximation of wind vector components based on usual on-board sensor signals is described.

SOIL

79-1765

Dynamic Shear Modulus and Damping in Additive-Treated Expansive Soils

W. Au

Ph.D. Thesis, Rutgers Univ., The State Univ. of New Jersey (New Brunswick), 212 pp (1978)
UM 7910364

Key Words: Clay soils, Dynamic shear modulus, Energy dissipation, Resonant bar technique

An experimental study of the dynamic properties of an expansive clay soil (sodium bentonite) treated with lime, salt, and a lime-salt combination is reported. Dynamic properties in terms of dynamic shear modulus and energy dissipation characteristics are determined by resonant column technique. The major test parameters considered are as follows: confining pressure and shear strain amplitude for the testing apparatus; degree of saturation, void ratio, soil structure, type of treatment and treatment level for the soil.

79-1766

Effect of Stress Condition on Dynamic Properties of Sand

E. Yanagisawa

Dept. of Civil Engrg., Tohoku Univ., Sendai, Japan, Tech. Repts., Tohoku Univ., 43 (2), pp 363-370 (1978) 10 figs, 7 refs

Key Words: Sands, Compression tests, Dynamic shear modulus, Damping coefficients

Shear modulus and damping factors of sand specimens in triaxial compression are determined by resonant column tests. Effects of octahedral normal stress and shear stress on the dynamic properties of sand are studied by applying stress in various ways, and an isogram of the shear modulus is drawn in principal stress coordinates. An empirical equation for evaluating the shear modulus of sand is derived from the test results.

VISCOELASTIC

(See No. 1819)

EXPERIMENTATION

BALANCING

79-1767

Balancing Technique for the Control of Vibrating Electromechanical Systems (Entkopplungsverfahren zur Regelung schwingungsfahiger elektromechanischer Systeme)

L. Litz

Mess und Regeleungstechnik '78, Tendenzen U. Impulse. Annual mtg. of the VDI/VDE-Gesellschaft Mess-und Regelungstechnik (GMR) Neu-Ulm 1978. VDI-Berichte No. 328, VDI Verlag GmbH: Düsseldorf, 1978, pp 59-68, 14 figs, 7 refs

(In German)

Key Words: Balancing techniques, Vibrating structures, Shafts

An example is used to illustrate the balancing of vibrating systems by the application of classical methods and the phase space theory. A skillful combination of both concepts produces good results with a minimal effort.

79-1768

Vibration Monitoring of Industrial Centrifuges - The Economic Spin-Offs

Noise Control Vib. Isolation, 10 (4), pp 153-154 (Apr 1979)

Key Words: Balancing techniques, Centrifugal pumps

An out-of-balance monitor for variable speed industrial centrifuges is described. The monitor is incorporated in the machine's control circuitry, but it also can be fitted to existing machines.

DIAGNOSTICS

(Also see No. 1740)

79-1769

Using Signature Analysis for Maintenance Planning

P.E. Babson

Res. and Dev. Division, Mechanical Technology, Inc., Turbomach. Intl., 19 (2), pp 42-45 (Mar 1978)

Key Words: Diagnostic techniques, Machinery vibration, Signatures

Troubleshooting rotating machinery dynamics related problems through observation and analysis of vibration characteristics, or signatures, is a widely accepted and rapidly

developing procedure. More emphasis is being placed upon systems and techniques which identify incipient failure modes of operation. The goal is to prevent catastrophic failures and to permit scheduling of maintenance for periods of minimum downtime penalty. Approaches to achieve this goal currently vary from periodic use of relatively simple hand held devices to continuous surveillance by complex, computer controlled diagnostic systems. The key is deciding what is cost-effective for each particular situation.

79-1770

A Guide to Better Spectrum Analysis

H.J. Bickel and A.J.R. Lord

Nicolet Scientific Corp., Noise Control Vib. Isolation, 10 (4), pp 127-131 (Apr 1979) 13 figs

Key Words: Spectrum analyzers, Measuring instruments, Vibration measurement, Diagnostic instrumentation

Within seconds a high performance spectrum analyzer presents to an operator a picture of vibration, noise, or other data in terms of frequency content. A source of noise and vibration can frequently be located by its characteristic frequency signature. Changes in test conditions appear as changes in the distribution of frequencies -- a screw tightened, a transducer relocated, a bearing aligned. The successful application of spectrum analysis techniques requires careful interpretation of spectrum data including consideration of possible sources of distortion and errors in such data.

79-1771

Analysis of Profile Shaft Joint Damage (Schädigungsanalyse von Profilwellenverbindungen)

J. Müller and R. Grewatsch

Wilhelm-Pieck Univ. Rostock, German Dem. Rep., Maschinenbautechnik, 28 (4), pp 157-159 (Apr 1979) 12 figs, 12 refs

(In German)

Key Words: Diagnostic techniques, Testing techniques

The experimental results presented indicate that it is not sufficient to detect a damage, but its cause should also be found. The authors discuss the application of metallographic techniques for the analysis of complicated damage phenomena. The technique is illustrated in an analysis of a shaft-hub connection.

EQUIPMENT

79-1772

Theoretical and Laboratory Study of Deep-Based Structures. Volume 1. Triaxial Machine for Static and Dynamic Testing of 12-Inch Diameter Rocks

P.E. Senseny and H.E. Lindberg

SRI International, Menlo Park, CA, Rept. No. DNA-4425F-1, AD-E300 404, 139 pp (Dec 1977)

AD-A063 487/3GA

Key Words: Test equipment, Underground structures, Linings

Design and fabrication of large-scale testing machines for static and dynamic testing of rock cavity reinforcement is described. The machine is patterned after a smaller prototype developed previously for DNA.

INSTRUMENTATION

(Also see No. 1770)

79-1773

Vibration Measurement - An Introduction to Piezoceramic Accelerometers and Associated Instrumentation - Part 1

D. Purdy

D.J. Birchall, Ltd., Noise Control Vib. Isolation, 10 (4), pp 140-142 (Apr 1979) 7 figs

Key Words: Accelerometers, Measuring instruments, Vibration measurement

This article is intended for those who have an understanding of engineering concepts, but have only a limited knowledge of vibration measurement. Further information may be obtained from various sources, a number of which are suggested in the final section.

79-1774

Federal Aviation Administration Integrated Noise Model

Office of Environmental Quality, Federal Aviation Admin., Washington, D.C., 16 pp (Apr 1978)

N79-17662

Key Words: Noise measurement, Aircraft noise, Computer-aided techniques

The Department of Transportation (DOT)/Federal Aviation Adminstration (FAA) developed a valuable noise-simulation computer-based tool for describing and defining the impact of aircraft noise around an airport. This tool, known as the Integrated Noise Model (INM), became available to the public in 1977, and is useful in assessing actual or predicted airport noise impacts. The INM takes into account all pertinent impact parameters including types and numbers of aircraft operating at the airport, flight tracks, operating procedures, and time of day of aircraft operations. This brochure is intended to familiarize the reader with the capabilities and characteristics of the INM. It also provides a better understanding of aircraft noise, the need for the INM, and its potential applications.

79-1775
A Laser Interferometer for Measuring Linear Vibration
D.G. Simpson and D.G.S. Lamb
National Engrg. Lab., East Kilbride, UK, Rept. No. NEL-652, 12 pp (Apr 1978)
N79-17203

Key Words: Lasers, Interferometers, Measuring instruments, Vibration measurement

A reference-beam type interferometer for the measurement of vibration is described. In the technique used, laser light reflected from a vibrating object is shifted in frequency (Doppler shift). The system offers a method for measuring vibration in situations where the use of conventional transducers would be impractical.

SCALING AND MODELING

79-1776
Structural Behavior of a Skew, Reinforced Concrete, Box Girder Bridge Model. Volume 1. Design
R.E. Davis
Div. of Structures, California State Dept. of Transportation, Sacramento, CA, Rept. No. 624187, FHWA/CA/ST-4187-78-01, 307 pp (Jan 1978)
PB-290 894/5GA

Key Words: Bridges, Reinforced concrete, Supports, Test models

A two-span, continuous, reinforced concrete, box girder bridge is modeled, instrumented and tested at the University of California, Berkeley, to assess anomalies in structural behavior by comparison with previously observed behavior of a straight and curved model of the same scale, on orthogonal and radial supports, respectively. Methods used in the model design are described in detail in this preliminary report.

TECHNIQUES

(Also see Nos. 1736, 1737, 1738, 1739, 1771)

79-1777
Standard Methods for Measuring the Airborne Noise from Hydraulic Pumps
A. Crook and R.A. Heron
BHRA Fluid Engrg., Noise Control Vib. Isolation, 10 (4), pp 145-151 (Apr 1979) 12 figs, 4 refs

Key Words: Pumps, Hydraulic systems, Measurement techniques, Standards

The authors discuss noise measurement techniques generated by hydraulic pumps as specified in the ISO test code 4412 and ISO 3740.

79-1778
A Measurement Technique for Low Frequencies
T.V. Rama Murthy and M.K. Kumar
Systems Engrg. Div., National Aeronautical Lab., Bangalore 560 017, India, J. Phys. E. (Sci. Instr.), 12, pp 187-188 (Mar 1979) 2 figs, 3 refs

Key Words: Measurement techniques, Low frequencies

A technique for the measurement of frequency within a cycle of a periodic input is described. This can be useful for quicker measurement of low frequencies.

79-1779
A Vibration Technique for Non-Destructively Assessing the Integrity of Structures

R.D. Adams, P. Cawley, C.J. Pye, and B.J. Stone
Univ. of Bristol, J. Mech. Engr. Sci., 20 (2), pp 93-100 (Apr 1978) 8 figs, 4 tables, 4 refs

Key Words: Nondestructive tests, Vibration measurement, Natural frequencies, Bars, Variable cross section

A method of non-destructively evaluating the integrity of structures is described and applied to structures for which a one-dimensional analysis is satisfactory. It is shown how vibration measurements made at a single station in the structure can be used in conjunction with a suitable theoretical model, to indicate both the location and the magnitude of a defect. Receptance analysis is used, but the principle is equally applicable to other techniques of mathematical analysis. Experimental results are obtained on a variety of components, including straight prismatic bars, a doubly-tapered bar, and an automobile camshaft, excellent agreement between the predicted and actual damage sites being obtained. The axial mode of vibration is generally used, although some tests are also carried out successfully in torsion.

79-1780
Measurement of Force and Mass under Influence of Unwanted Acceleration (Messung von Kraft und Masse unter Einfluss von Störbeschleunigungen)
U. Milz
Measurement of Force and Mass., Intl. Conf. of the Intern. Messtechn. Konföder., Braunschweig, 13-15 Sept 1978, VDI Bericht 312, VDI Verlag GmbH: Düsseldorf 1978, pp 135-141, 16 figs, 8 refs
(In German)

Key Words: Measurement techniques, Vibration measurement

Measurement of force is impossible without any mass. Forces variable with time or movements will cause dynamic errors. Using total compensation, weighing systems will be acceleration-compensated and result in short transient time.

COMPONENTS

SHAFTS

79-1781
On the Vibrations of a Shaft with Nonlinear Spring Characteristics
T. Yamamoto and Y. Ishida
Dept. of Mech. Engrg., Nagoya Univ., Mem. Fac. Engr. Nagoya Univ., 30 (1), pp 59-109 (May 1978) 39 figs, 6 tables, 18 refs

Key Words: Shafts, Nonlinear springs, Forced vibration

A particular vibration phenomena at the major critical speed when rotating spring characteristics and rotating difference in shaft stiffness exist is discussed. Nonlinear forced oscillations in a shaft system with static nonlinearity are considered. Various kinds of subharmonic and summed-and-differential harmonic oscillations are obtained experimentally. Nonlinear forced oscillations are also discussed theoretically.

BEAMS, STRINGS, RODS, BARS

(Also see Nos. 1800, 1825, 1826, 1855)

79-1782
Vibrations of Relaxed Piston Rings in the Plane (Schwingungen entspannter Kolbenringe in der Ebene)
F.A. Emmerling and D. Teichmann
VDI Z., 121 (4), pp 153-158 (Feb 11, 1979) 7 figs, 4 refs
(In German)

Key Words: Beams, Curved beams, Natural frequencies, Torsional vibration, Mode shapes

Natural torsional frequencies and natural modes of vibration of a curved beam with a variable radius of curvature are calculated. The results of calculation are applicable in the manufacture of relaxed piston rings.

79-1783
Non-Linear Non-Planar Resonant Oscillations in Fixed-Free Beams with Support Asymmetry
M.R.M. Crespo Da Silva and C.C. Glynn
Dept. of Engrg. Science, Univ. of Cincinnati, Cincinnati, OH 45221, Intl. J. Solids Struc., 15 (3), pp 209-219 (1979) 7 figs, 41 refs

Key Words: Beams, Coupled response, Resonant response

The order-three, integro differential, non-linear equations of motion for an inextensional beam are analyzed to investigate non-linear resonant coupling effects between the non-planar free oscillation modes of a fixed-free beam with asymmetric support conditions. The transition curves that separate non-linear resonant and non-resonant types of motions for the beam, and the main characteristics of the non-linear motions, are determined analytically.

79-1784

Stability of a Non-Uniform Beam on a Viscoelastic Foundation with a Shear Layer Subjected to a Non-Conservative Force

R.C. Kar

Dept. of Mech. Engrg., Indian Inst. of Tech., Kharagpur 721302, India, J. Sound Vib., 63 (4), pp 517-525 (Apr 22, 1979) 7 figs, 8 refs

Key Words: Beams, Viscoelastic foundations, Variational methods

The stability of a cantilever beam of linearly variable rectangular cross-section lying on a viscoelastic foundation with a shear layer subjected to a circulatory force at its free end is investigated. The materials of the beam and the foundation are assumed to be Kelvin-type solids. Approximate values of the critical loads are calculated on the basis of an adjoint variational principle. The influence of geometric and material properties of the system on the critical load is depicted through several graphs.

79-1785

Large Deflection Response of Elastic/Visco-Plastic Beams Under Combined Tension and Bending

S.J. Yim

Ph.D. Thesis, The Pennsylvania State Univ., 206 pp (1978)

UM 7909151

Key Words: Beams, Elastic properties, Viscoplastic properties

The prediction of the dynamic responses of elastic/viscoplastic clamped beams between immovable vertical supports subjected to rapid base motion is presented by including the material rate sensitivity. Large deflections are considered and the finite difference method is used to solve this non-linear problem. Experiments are carried out to check the validity of the analytical method and to determine the best value of the rate-sensitive parameter in the constitutive equation.

79-1786

Non-Linear Free Vibrations of Inextensible Beams

K. Takahashi

Dept. of Civil Engrg., Nagasaki Univ., Nagasaki, Japan, J. Sound Vib., 64 (1), pp 31-34 (May 8, 1979) 1 fig, 4 tables, 2 refs

Key Words: Beams, Free vibration, Galerkin method, Harmonic balance method

Non-linear free vibrations of inextensible clamped-free and free-free beams are analyzed by using Galerkin's method and the harmonic balance method.

79-1787

Measurement of the Traction Force in Conductors by Transversal Oscillation (Die Messung der Zugkraft in Leitungsseilen mit Hilfe von Transversalwellen)

K. Schuller

Measurement of Force and Mass, Intl. Conf. of the Intern. Messtechn. Konföder., Braunschweig, 13-15 Sept 1978, VDI Bericht 312, VDI-Verlag GmbH: Düsseldorf 1978, pp 157-167, 2 figs, 8 tables, 8 refs (In German)

Key Words: Cables (ropes), Vibration measurement

Starting from the well-known transverse vibration technique of measuring the tension in axially loaded cables, equations are established in the paper taking into account the cable bending stiffness and the actual chain-type equilibrium shape in the gravitational field.

79-1788

On a Problem in the Dynamics of Looped Cables

R.D. Parbery

The Univ. of Newcastle, New South Wales, J. Mech. Engr. Sci., 20 (2), pp 85-91 (Apr 1978) 6 figs, 1 table, 12 refs

Key Words: Cables (ropes)

The paper describes a problem in the dynamics of cables. Equations of motion are derived for a cable suspended by its ends which are subjected to prescribed vertical movement. A number of approximate solutions of the quasistatic type are investigated and numerical examples are calculated to show the effect of the acceleration and velocity of the end points.

79-1789

A Finite Element Approach for Cable Problems

H. Ozdemir

Earthquake Engrg. Systems, Inc., San Francisco, CA 94111, Intl. J. Solids Struc., 15 (5), pp 427-437 (1979) 6 figs, 3 tables, 17 refs

Key Words: Cables (ropes), Finite element technique

A finite element approach is proposed for the static and dynamic nonlinear analysis of cable structures. Starting from the stress equations of equilibrium, a variational formulation is derived in which the static and kinematic variables are measured in some previous configuration of the body. To discretize this variational form of equilibrium equations, Lagrangian functions are employed to interpolate the curved geometry of each element and only displacement continuity is enforced between element nodes. The finite element matrices resulting from the operations of linearization and discretization are derived. Sample analyses are presented to demonstrate the utility and reliability of the proposed elements.

79-1790

Blast Response of Lattice Mast - Event Dice Throw

B.G. Laidlaw

Defence Res. Establishment, Suffield, Ralston, Alberta, Canada, Rept. No. DRES-TP-452, 37 pp (Dec 1978)

AD-A063 562/3GA

Key Words: Antennas, Dynamic tests, Blast loads, Computer programs

Experimental results are presented for the response of a 30 foot high lattice mast structure to air blast loading in the 628 ton AN/FO (ammonium nitrate-fuel oil) explosion known as Event Dice Throw which was held in October 1976 at the White Sands Missile Range, New Mexico.

BEARINGS

79-1791

Static and Dynamic Performance Characteristics of an Orifice-Compensated Hydrostatic Journal Bearing

D.V. Singh, R. Sinhasan, and R.C. Ghai

Military Technical College, Baghdad, Iraq, ASLE, Trans., 22 (2), pp 162-170 (Apr 1979) 12 figs, 3 tables, 17 refs

Key Words: Journal bearings, Periodic response, Stiffness coefficients, Damping coefficients, Finite element technique

The fluid film lubrication equation for a zero-speed, orifice-compensated, multipocket hydrostatic journal bearing is solved by a finite element method for determining its steady-state performance and the dynamic stiffness and damping coefficients. For stability studies, critical mass for the linearized system has been determined by Routh's criterion. By discretizing time and using the Runge-Kutta method, motion trajectories of the journal center have been theoretically determined for a small aribtrary initial disturbance.

79-1792

Analytical Dynamics of Partial Journal Bearings with Applications

D.F. Li, P.E. Allaire, and L.E. Barrett

Univ. of Virginia, Charlottesville, VA 22901, ASLE, Trans., 22 (2), pp 99-112 (Apr 1979) 11 figs, 24 refs

Key Words: Journal bearings, Dynamic structural analysis

A variational approach has been employed to solve Reynolds' equation for a finite length partial journal bearing. The pressure is obtained as a doubly infinite sine series and the load capacity can be expressed, for some bearings, as a simple sum of coefficients.

79-1793

Stiffness and Damping Coefficients for the Five-Pad Tilting-Pad Bearing

J.C. Nicholas, E.J. Gunter, and P.E. Allaire

Univ. of Virginia, Charlottesville, VA 22901, ASLE, Trans. 22 (2), pp 113-124 (Apr 1979) 16 figs, 2 tables

Key Words: Bearings, Tilting pad bearings, Stiffness coefficients, Damping coefficients, Finite element technique

Stiffness and damping coefficients are presented for the 5-pad tilt-pad bearing for various preloads, offsets, length to diameter ratios and pad loadings (on and between pad). Finite elements and the pad assembly method are used to calculate these coefficients and the effects of the unloaded pads are included. Design curves suitable for tilt-pad bearings in widespread industrial use are presented.

79-1794

Wear Tests with Spherical PTFE-Bearings of Type AMPEP

G. Carlsson

Structures Dept., Aeronautical Research Inst. of Sweden, Stockholm, Sweden, Rept. No. FFA-TN-HU-1955, 16 pp (June 1978)

N79-18325

Key Words: Bearings, Angular vibration, Wear

Tests are carried out at room temperature with 10 spherical bearings. The purpose is to measure the wear and rotational torque at constant radial load with two different fittings and also at varying radial load in blocks.

79-1795

Evaluation of Shuttle Turbopump Bearings

K.D. Dufrane and J.W. Kannel

Battelle Columbus Labs., OH, Rept. No. NASA-CR-150906, 38 pp (Nov 22, 1978)

N79-18321

Key Words: Bearings, Turbomachinery, Pumps

This report presents the methods used and the results of load track analysis on one set of bearings removed from a high pressure liquid oxygen turbopump which had been subjected to SSME static firing tests. This type of analysis was found useful in determining bearing operating conditions and for verifying rotor dynamics computer models.

BLADES

79-1796

Analysis of an Unsteady Aerodynamic Force on a Blade Due to Ununiform Amplitude Gusts

K. Ishihara and M. Funakawa

The Tech. Lab., Kawasaki Heavy Industries, Akashi, Japan, Bull. JSME, 22 (166), pp 529-536 (Apr 1979) 11 figs, 2 tables, 7 refs

Key Words: Blades, Airfoils, Aerodynamic loads, Wind-induced excitation

Lift fluctuations of a cambered blade with angle of attack under periodic gusts with ununiform amplitude are studied by using vortex theory.

79-1797

Propeller Blade Pressure Distribution Due to Loading and Thickness Effects

S. Tsakonas, W.R. Jacobs, and M.R. Ali

Fluid Dynamics Div., Davidson Lab., Stevens Inst. of Tech., Hoboken, NJ, J. Ship Res., 23 (2), pp 89-107 (June 1979) 21 figs, 15 refs

Key Words: Marine propellers, Propeller blades, Geometric effects

A theoretical approach is developed and a computational procedure adaptable to a high-speed digital computer is established for the evaluation of the blade pressure distribution of a marine propeller due to thickness and loading effects. The dual role of the blade thickness is considered. The contribution of the nonplanar thickness to the propeller loading and pressure distribution and the effect of the flow distortion thickness are studied by means of the thin body approximation. The surface integral equation which relates the unknown loading to the known velocity distribution on the blades is solved by the mode approach in conjunction with the lift operator technique. The analysis treats both design and off-design conditions in steady-state and unsteady flows, and the proper chordwise modes are selected for each condition.

79-1798

Inertial Dynamics of a General Purpose Rotor

R.W. DuVal

NASA Ames Research Ctr., Moffett Field, CA, Rept. No. NASA-TM-78557; A-7731, 34 pp (Mar 1979) N79-18916

Key Words: Rotors, Rotor blades, Inertial forces

The inertial dynamics of a fully articulated stiff rotor blade are derived with emphasis on equations that facilitate an organized programming approach for simulation applications. The model for the derivation includes hinge offset and six degrees of freedom for the rotor shaft. Results are compared with the flapping and lead-lag equations currently used in the Rotor Systems Research Aircraft simulation model and differences are analyzed.

79-1799

Containment of Composite Fan Blades. Quarterly Progress Report, 1 Apr - 30 June 1977

A.P. Coppa and C.L. Stotler

General Electric Co., Philadelphia, PA, Rept. No. NASA-CR-158168, 15 pp (1977) N79-18978

Key Words: Protective shields, Fan blades

The development of containment concepts for use with large composite fan blades, taking into account the frangible nature of composite blades is considered. Aspects of the development program include: an analysis to predict the interaction between a failed fan blade and the blade containment structure; scaling factors to allow impact testing using subscale containment rings and simulated blades; the design and fabrication of containment systems for further evaluation in a rotating rig test facility; evaluate the test data against the analytically predicted results; and determine overall systems weights and design characteristics of a composite fan stage installation and compare to the requirements of an equivalent titanium fan blade system. Progress in the blade impact penetration tests and the design and fabrication of blade containment systems is reported.

CYLINDERS

79-1800

Pulse Propagation in Coaxial Circular Cylinders of Two Elastic Phase Materials

Z. Holtzman and J.M. Litshitz

Technion-Israel Inst. of Technology, Haifa, Israel, J. Acoust. Soc. Amer., 65 (5), pp 1182-1189 (May 1979) 10 figs, 11 refs

Key Words: Circular cylinders, Rods, Natural frequencies, Modal analysis

Pulse propagation in a finite coaxial circular cylinder made of two elastic materials is solved numerically. In the first stage the natural frequencies of the free rod, including those of the higher modes, are determined and used to qualitatively predict dispersion of a pulse. In the second stage modal analysis is used to determine dispersion of the pulse and to obtain distribution of axial stress and displacement and shear stress along the radius of the cylinder.

79-1801

Flow Induced by a Torsionally Oscillating Wavy Cylinder

P.W. Duck

Dept. of Mathematics, Imperial College, London, UK, Quart. J. Mech. Appl. Math., 32 (1), pp 73-91 (Feb 1979) 6 figs, 6 refs

Key Words: Cylinders, Vibrating structures, Torsional response, Fluid-induced excitation

The flow induced by a cylinder, with a small amplitude sinusoidal surface perturbation, torsionally oscillating in an unbounded fluid is considered. In particular the Taylor number is close to its critical value, and the interaction between the forced and the natural solutions is investigated for a number of different wavelengths of surface distortion.

79-1802

Simple Apparatus for Measuring the Dynamic Shear Modulus of Cylindrical Specimens

H.M. Simpson and J. Pearson

Dept. of Physics, Wright State Univ., Dayton, OH 45435, Rev. Scientific Instr., 50 (4), pp 418-420 (Apr 1979) 2 figs, 22 refs

Key Words: Cylinders, Vibrating structures, Torsional vibration, Dynamic shear modulus, Measuring instruments

An apparatus is described which has been used to determine the shear modulus of cylindrical specimens vibrating in the torsional mode. The specimens are maintained in self-excited vibration by an eddy-current driver, an eddy-current pickup, and a feedback circuit consisting of a phase-locked-loop and an amplitude control module.

79-1803

Across-Flow Response Due to Vortex Shedding: Isolated Circular Cylindrical Structures in Wind or Gas Flows

Engrg. Sciences Data Unit, London, UK, Rept. No. ESDU-78006; ISBN-0-85679-229-2, 59 pp (Oct 1978)

N79-18911

Key Words: Cylinders, Circular cylinders, Vortex shedding, Vortex-induced vibration, Fatigue tests

Data is presented for estimating the maximum oscillation amplitudes induced by vortex shedding on flexible structures and the critical flow speeds at which they occur. This information is also important in the fatigue analysis of a structure. Only isolated structures of circular cross section are treated.

DUCTS

79-1804

The Flow Noise Level at Microphones in Flow Ducts

W. Neise and B. Stahl

Deutsche Forschungs- und Versuchsanstalt f. Luft- und Raumfahrt e.v., Institut f. Turbulenzforschung, Berlin, Germany, J. Sound Vib., 63 (4), pp 561-579 (Apr 22, 1979) 10 figs, 17 refs

Key Words: Ducts, Sound measurement, Measurement techniques

In this paper two procedures for determining the flow noise level are described. For the first method, the mean flow velocity and the turbulence level have to be known to estimate the flow noise level as a function of duct diameter and frequency. For the second method knowledge of only the mean flow velocity is required. The procedure involves two measurements: one with a microphone fitted with a conventional nose cone and one with a microphone fitted with a slit-tube. The slit-tube is a special device for reducing the flow noise level. Finally, guidelines are given for sound measurements in the presence of flow and for the use of a microphone with a slit-tube under unusual temperature conditions or in gases other than air.

79-1805

Finite Amplitude Two-Dimensional Waves in a Rectangular Duct Induced by Arbitrary Periodic Excitation

J.H. Ginsberg

School of Mech. Engrg., Purdue Univ., West Lafayette, IN 47907, J. Acoust. Soc. Amer., 65 (5), pp 1127-1133 (May 1979) 5 figs, 1 table, 13 refs

Key Words: Ducts, Elastic waves, Sound propagation, Periodic excitation

The nonlinear two-dimensional acoustic waves that occur within a rectangular duct of semi-infinite length as the result of periodic excitation are determined by an asymptotic method. A regular perturbation expansion is employed to obtain the velocity potential as a solution of a nonlinear wave equation. Uniformly valid expressions for the particle velocity components and pressure are then derived with the aid of a coordinate straining transformation that features both spatial coordinates.

LINKAGES

(Also see No. 1860)

79-1806

Calculation of Dynamically Loaded Bolted Joints (Berechnung dynamisch beanspruchter Schraubenverbindungen)

M. Backasch and J. Dobberschütz

VEB ROBUR-Werke Zittau, German Dem. Rep., Maschinenbautechnik, 28 (4), pp 163-165 (Apr 1979) 5 figs, 2 tables, 7 refs

(In German)

Key Words: Joints (junctions), Bolts, Computer programs, Algorithms

An algorithm for the calculation of roughly dimensioned, dynamically loaded bolted joints is presented. A computer program, ALGOL-R 300 is also available.

79-1807

The Dynamics of a Hooke's Joint Gyroscope with Non-Orthogonal Flexure Axes

C.H.J. Fox and J.S. Burdess

Univ. of Newcastle upon Tyne, J. Mech. Engr. Sci., 20 (2), pp 79-84 (Apr 1978) 4 figs, 3 refs

Key Words: Gyroscopes, Universal joints, Natural frequencies

The dynamical characteristics of a Hooke's joint gyroscope with non-orthogonal flexure axes are described. For both the tuned and untuned cases, the response to an applied rate of turn has been assessed and errors arising from flexure axis non-orthogonality are identified.

PIPES AND TUBES

79-1808

Experimental Studies of Tube Frettings in Steam Generators and Heat Exchangers

P.L. Ko

Chalk River Nuclear Labs., Atomic Energy of Canada, Limited, Chalk River, Ontario, Canada, J. Pressure Vessel Tech., Trans. ASME, 101 (2), pp 125-133 (May 1979) 23 figs, 10 refs

Key Words: Tubes, Heat exchangers, Boilers, Fluid-filled containers, Fluid-induced excitation

The steam generators in CANDU power plants have a design life of 30 years; it is, therefore, essential that design criteria be developed to minimize tube fretting and to establish acceptable limits of vibration. Standard equipment has been developed to study the effect on tube fretting due to various parameters, such as tube/tube-support interaction, materials combinations, and support geometry. Tests have been conducted in water and steam at boiler operating temperature and at room temperature.

79-1809

Research on Wave Phenomena in Hydraulic Lines (4th Report, Coupling Between Oil Pulsation and Longitudinal Pipe Vibration)

S. Washio, T. Konishi, and T. Sonoda

Faculty of Engrg., Kyoto Univ., Sakyo-ku, Kyoto, Japan, Bull. JSME, 22 (166), pp 570-576 (Apr 1979) 11 figs, 1 table, 13 refs

Key Words: Pipes (tubes), Vibration damping, Fluid-induced excitation, Longitudinal vibration

The longitudinal vibration of a pipe caused by oil pulsation in it is investigated. The coupled vibrations of a pipe and oil are theoretically analyzed. A viscoelastic model composed of a Voigt model and a series spring is introduced to represent the pipe vibration with damping. Another theoretical analysis considering distributed interactions through a pipe wall is also made and their significance is numerically estimated. The vibration tests of a straight steel pipe containing oil are carried out. The dynamic pressures of oil and the longitudinal accelerations of a pipe are measured and the obtained frequency characteristics are compared with the theoretical ones.

PLATES AND SHELLS

79-1810

Vibration and Stability of Beam Reinforced Polar Orthotropic Annular Plates of Uniform and Variable Thickness

C.T. Dyka

Ph.D. Thesis, The Univ. of Connecticut, 79 pp (1978) UM 7911363

Key Words: Plates, Variable cross section, Beam-plate systems, Natural frequencies

The natural frequencies and buckling loads for a radially compressed polar orthotropic annular plate (of both uniform and variable thickness) surrounded on its inner and outer boundaries by edge beams of rectangular cross section are determined. The inner and outer edge beams are simply supported and subjected to uniform, radial, compressive loadings. For the uniformly thick plate, the annular plate, edge beam system is spinning at a constant angular velocity. The natural frequencies and buckling loads are determined for both the axisymmetric and higher modes.

79-1811

Vibrations of Annular Plates of Variable Thickness

C.T. Dyka and J.F. Carney, III

Uniroyal, Inc., Middlebury, CT, ASCE J. Engr. Mech. Div., 105 (EM3), pp 361-370 (June 1979) 5 figs, 9 refs

Key Words: Plates, Variable cross section, Vibration response

An exact solution for the circular frequencies of a polar orthotropic annular plate of uniform and parabolic thickness under the action of in-plane forces is presented. The

annular plate is reinforced with simply supported edge beams at both the inner and outer boundaries. The edge beams are subjected to uniform, radial compressive loadings. Frequency parameters are determined for both axisymmetric and high modes.

79-1812

Transverse Vibrations of Rectangular Plates with Thickness Varying in Two Directions and with Edges Elastically Restrained Against Rotation

P.A.A. Laura, R.O. Grossi, and G.I. Carneiro
Inst. of Applied Mechanics, 811 Base Naval Puerto Belgrano, Argentina, J. Sound Vib., 63 (4), pp 499-505 (Apr 22, 1979) 3 figs, 9 refs

Key Words: Plates, Rectangular plates, Variable cross section, Flexural vibration

The title problem is solved in the case of linear variation of the thickness in the x- and y-directions, a simple polynomial coordinate function being used. An approximate but quite convenient frequency equation is derived by using the Rayleigh method.

79-1813

Axisymmetric Seismic Response of a Thick Circular Plate Supporting Many Rods by Modal Synthesis

T.H. Lee
National Taiwan Univ., Taipei, Taiwan, Republic of China, Intl. J. Earthquake Engr. Struc. Dynam., 7 (3), pp 235-251 (May/June 1979) 15 figs, 3 tables, 16 refs

Key Words: Plates, Circular plates, Supports, Seismic response, Modal synthesis

Dynamic response of a thick, horizontal, circular plate supporting a large number of slender rods subjected to uniform boundary motion in the vertical direction has been studied by synthesizing component modes of continuous substructures. The excitation considered corresponds to the vertical component of boundary movement produced by earthquake disturbances and the axisymmetric response problem was solved. Mindlin theory was used to formulate the component equations of the plate which is treated as the main component in a modal synthesis technique.

79-1814

Dynamic Plastic Response of Circular Plates with Transverse Shear and Rotatory Inertia

N. Jones and J.G. de Oliveira
Dept. of Ocean Engrg., Massachusetts Inst. of Tech., Cambridge, MA, Rept. No. 78-9, 44 pp (Dec 1978) AD-A063 561/5GA

Key Words: Plates, Circular plates, Dynamic plasticity, Transverse shear deformation effects, Rotatory inertia effects

The response of a simply supported circular plate made from a rigid perfectly plastic material and subjected to a uniformly distributed impulsive velocity is developed. Plastic yielding of the material is controlled by a yield criterion which retains the transverse shear force as well as bending moments and the influence of rotatory inertia is included in the governing equations. Various equations and numerical results are presented which may be used to assess the importance of transverse shear effects and rotatory inertia for this particular problem.

79-1815

Method by Functionals for Determining the Frequencies of Lateral Vibration of Membranes and Plates

H. Takeyama
Dept. of Precision Engrg., Tohoku Univ., Sendai, Japan, Tech. Repts., Tohoku Univ., 43 (2), pp 285-302 (1978) 2 figs, 3 refs

Key Words: Plates, Membranes, Lateral vibration

The method for deciding characteristic values by the new functionals is extended to the characteristic value problems of two dimensions. The method for finding the frequencies of lateral vibration of membranes and plates by the functionals of the latter type is shown with four examples for square and circular membranes and plates.

79-1816

Transient and Time-Harmonic Waves in Elastic Plates

H. Cohen, A.H. Shah, and D.P. Thambiratnam
Dept. of Civil Engrg., Univ. of Manitoba, Winnipeg, Manitoba, Canada R3T 2N2, Intl. J. Solids Struc., 15 (5), pp 395-404 (1979) 2 figs, 13 refs

Key Words: Plates, Wave propagation, Harmonic waves

This paper deals with transient wave propagation in elastic homogeneous and isotropic plates, in terms of displacement discontinuities at the wave front. The problem of steady state time harmonic waves is dealt with in terms of asymptotic series expansion. The possible wave types along with the general transport-induction equations for each type are given, and the interrelationship between transient and time harmonic waves is discussed. Special constrained wave motions which allow uncoupling of the various possible wave types are defined. Several illustrative examples of the theory developed are given.

79-1817

Large Amplitude Free Flexural Vibrations of Thin Plates of Arbitrary Shape

C. Mei, R. Narayanaswami, and G.V. Rao
Dept. of Engrg. Mechanics, Univ. of Missouri-Rolla, Rolla, MO 65401, Computers Struc., 10 (4), pp 675-681 (Aug 1979) 5 figs, 5 tables, 17 refs

Key Words: Plates, Flexural vibrations, Free vibrations, Finite element technique

A finite element formulation is developed for analyzing large amplitude free flexural vibrations of elastic plates of arbitrary shape. Stress distributions in the plates, deflection shape and nonlinear frequencies are determined from the analysis. Linearized stiffness equations of motion governing large amplitude oscillations of plates, quasi-linear geometrical stiffness matrix, solution procedures, and convergence characteristics are presented. The linearized geometrical stiffness matrix for an eighteen degrees-of-freedom conforming triangular plate element is evaluated by using a seven-point numerical integration. Nonlinear frequencies for square, rectangular, circular, rhombic, and isosceles triangular plates, with edges simply supported or clamped, are obtained and compared with available approximate continuum solutions.

79-1818

Improved Frequency Resolution From Transient Tests with Short Record Lengths

P. Cawley and R.D. Adams
Dept. of Mech. Engrg., Univ. of Bristol, Bristol BS8 1TR, UK, J. Sound Vib., 64 (1), pp 123-132 (May 8, 1979) 5 figs, 2 tables, 13 refs

Key Words: Plates, Natural frequencies, Dynamic structural analysis, Fourier transformation

A method is described for improving the accuracy of the natural frequencies obtained from the Fourier transform of the structural response to an impulse. The natural frequencies of the aluminium plate obtained by this method are also compared with those measured when using steady state excitation. Excellent agreement is shown between the results obtained by using the two techniques.

79-1819

Vibrations of Three Layered Damped Sandwich Plate Composites

Y.P. Lu, J.W. Killian, and G.C. Everstine
David W. Taylor Naval Ship Res. and Dev. Center, Bethesda, MD 20084, J. Sound Vib., 64 (1), pp 63-71 (May 8, 1979) 7 figs, 16 refs

Key Words: Plates, Composite structures, Sandwich structures, Damped structures, Viscoelastic damping

Theoretical and experimental results are presented and discussed for the transverse driving point mechanical impedances of damped composite plates made up of a thin viscoelastic layer sandwiched between two elastic layers. Analytical results are determined by finite element approximations. Good correlations between the test data and analytical solutions are obtained over a wide frequency range for two configurations.

79-1820

A Study of Bending Waves in Fluid-Loaded Thick Plates

M. Pierucci and T.S. Graham
Electric Boat Div., General Dynamics Corp., Groton, CT 06340, J. Acoust. Soc. Amer., 65 (5), pp 1190-1197 (May 1979) 1 fig, 11 refs

Key Words: Plates, Fluid-induced excitation, Flexural waves

Exact, steady-state solutions, representing straight-crested free bending waves are calculated for the infinite Timoshenko-Mindlin plate with fluid loading. There are three different types of waves, two of which are roughly similar to plate waves in vacuum, and a third wave which is unique to fluid-loaded plates. The unusual behavior of this third free bending wave is the subject of this paper. Calculated solutions are presented as loci of complex free bending wavenumbers for steel plates and for different conditions of fluid loading.

79-1821

Acoustic Emission and Propagation of Elastic Pulses in a Plate

A.N. Ceranoglu

Ph.D. Thesis, Cornell Univ., 167 pp (1979)

UM 7910736

Key Words: Acoustic emission, Elastic waves, Plates

Analysis of transient response of an elastic, isotropic, homogeneous infinite plate due to point sources including an arbitrarily oriented concentrated force, single couple, double force, center of rotation, and a double couple without moment is presented in this thesis. These sources or a distribution of them can be used to model the mechanism of acoustic emission which is a phenomenon of rapidly releasing of localized strain energy in solid materials or structures.

79-1822

Modal Resonance Analysis of Acoustic Transmission and Reflection Losses in Viscoelastic Plates

W. Madigosky and R. Fiorito

Naval Surface Weapons Center, White Oak Lab., Silver Spring, MD 20910, J. Acoust. Soc. Amer., 65 (5), pp 1105-1115 (May 1979) 13 figs, 2 tables, 21 refs

Key Words: Plates, Viscoelastic properties, Acoustic transmission, Modal analysis

Transmission and reflection losses are calculated as functions of frequency thickness and incidence angle for single and multiple viscoelastic plates (steel, ABS, syntactic foam, neoprene, and Plexiglas) using a transfer matrix method modified to include complex wave velocities. The calculation of these velocities depends on four measurable material constants: longitudinal and shear phase velocities and absorption coefficients.

79-1823

Dynamic Plastic Analysis Using Stress Resultant Finite Element Formulation

P. Lukkunaprasit and J.M. Kelly

Chulalongkorn Univ., Bangkok, Thailand, Intl. J. Solids Struc., 15 (3), pp 221-240 (1979) 15 figs, 1 table, 44 refs

Key Words: Plates, Shells, Dynamic plasticity, Finite element technique

A stress resultant finite element formulation is developed for the dynamic plastic analysis of plates and shells of revolution undergoing moderate deformation. A nonlinear elastic-viscoplastic constitutive relation simulates the behavior of rate-sensitive and -insensitive materials. A local time step subdivision procedure is developed to stabilize the direct numerical integration of the system of nonlinear dynamic equations; satisfactory accuracy is obtained with large time steps.

79-1824

Non-Linear Free Vibrations of Conical Shells

T. Ueda

National Aerospace Lab., Tokyo, Japan, J. Sound Vib., 64 (1), pp 85-95 (May 8, 1979) 9 figs, 1 table, 19 refs

Key Words: Shells, Conical shells, Cylindrical shells, Plates, Numerical analysis

The non-linear characteristics of free vibrations of conical shells, including both circular cylinders and annular plates have been investigated. Donnell type theory is utilized to prescribe the shells and the trial functions of the assumed mode are obtained by means of the finite element method.

79-1825

Deformation and Stability of Wind-loaded Cooling Tower Shells (Deformation und Stabilität windbeanspruchter Kühlturmschalen)

H. Mang, R.H. Gallagher, L. Cedolin, and P. Torzicky

Institut f. Elastizitäts- und Festigkeitslehre, Technische Universität Wien, Karlsplatz 13, A-1040 Wien, Austria, Ing. Arch., 47 (6), pp 391-410 (1978) 11 figs, 4 tables, 35 refs

(In German)

Key Words: Cooling towers, Shells, Wind-induced excitation

The deformation and stability problem is formulated on the basis of originally non-conforming triangular curved finite elements with the help of a variational principle with subsidiary conditions. Then the deformation problem is solved numerically for an existing cooling tower shell. The subsequent stability analysis of this cooling tower shell agrees with the buckling safety computed by means of the finite element method and the minimum of buckling safety obtained with the help of Mungan's stability criterion.

79-1826

On Ovalling Oscillations of Cylindrical Shells in Cross-Flow

M.P. Paidoussis and C. Helleur

Dept. of Mech. Engrg., McGill Univ., Montreal, Quebec, Canada, J. Sound Vib., 63 (4), pp 527-542 (Apr 22, 1979) 10 figs, 14 refs

Key Words: Cylindrical shells, Chimneys, Wind-induced excitation

This paper presents an experimental investigation into the nature of the ovalling oscillation of cantilevered cylindrical shells, induced by cross-flow – a phenomenon which has been observed to occur in thin metal chimney stacks when subjected to sufficiently strong cross winds.

79-1827

Dynamic Elastic-Plastic Response of a Containment Vessel to Fluid Pressure Pulses

G. Nikolakopoulou and F. DiMaggio

Bell Labs., Whippany, NJ, Computers Struc., 10 (4), pp 659-667 (Aug 1979) 15 figs, 1 table, 13 refs

Key Words: Shells, Fluid-filled containers, Nuclear reactor components, Nuclear reactor containment, Elastic plastic properties

The dynamic analysis of the wall of a fluid-filled unstiffened nuclear containment vessel, to the fluid pressure exerted on it when the relief valve discharge piping is cleared, is extended into the plastic range using two versions of an elastic-plastic shell theory.

79-1828

Some Experiments on the Vibration of Hemispherical Shells Partially Filled with a Liquid

K. Komatsu and M. Matsushima

National Aerospace Lab., 1880 Jindaiji-Machi, Chofu, Tokyo, Japan, J. Sound Vib., 64 (1), pp 35-44 (May 8, 1979) 11 figs, 3 tables, 13 refs

Key Words: Shells, Hemispherical shells, Fluid-filled containers, Boundary value problems, Holographic techniques, Finite element technique

This paper describes experiments on the vibration of hemispherical shells partially filled with a liquid. The experiments are carried out under the following two boundary conditions: a clamped boundary condition and a free boundary condition. Holographic interferometry is applied in the experiment and the finite element method is used in the numerical analysis. The experimental data presented here are in good agreement with the numerical results.

79-1829

Correlation Between Vibrations and Buckling of Stiffened Cylindrical Shells Under External Pressure and Combined Loading

H. Abramovich, J. Singer, and A. Gruenwald

Dept. of Aeronautical Engrg., Technion-Israel Inst. of Tech., Haifa, Israel, Rept. No. TAE-326, 87 pp (Dec 1977)
N79-17258

Key Words: Shells, Cylindrical shells, Stiffened shells, Boundary condition effects

A vibration correlation technique for definition of the boundary conditions of stringer-stiffened shells, developed earlier for axial compression loading, is extended to the case of external pressure and axial compression. The techniques consist essentially of an experimental determination of the natural frequencies in vibration modes that resemble the buckling modes of a loaded shell, and assessment of the equivalent elastic restraints which represent the boundary conditions by comparison within theoretically predicted frequencies.

79-1830

The Influence of Practical Boundary Conditions on the Vibrations and Buckling of Stiffened Cylindrical Shells

J. Singer and H. Abramovich

Dept. of Aeronautical Engrg., Technion-Israel Inst. of Tech., Haifa, Israel, Rept. No. TAE-288, 58 pp (Mar 1978)
N79-17260

Key Words: Shells, Cylindrical shells, Stiffened shells, Boundary condition effects

A vibration correlation technique, consisting essentially of experimental determination of the frequencies under load and assessment of equivalent elastic restraints, is extended to realistic boundary conditions. Six shells with end conditions, simulating typical missile joints, are tested and ana-

lyzed. Lumping of end effects is studied and additional shells on laboratory type end rings with prescribed load eccentricity tested earlier are compared. A method is developed for detection of load eccentricity from vibration tests and assessment of equivalent end restraints.

79-1831

Vibration Characteristics of Thin Circular Cylinders

C.B. Sharma

Dept. of Mathematics, Univ. of Manchester Inst. of Science and Tech., Manchester M60 1QD, UK, J. Sound Vib., 63 (4), pp 581-592 (Apr 22, 1979) 6 figs, 2 tables, 11 refs

Key Words: Shells, Cylindrical shells, Circular shells, Vibration response, Variational methods

In this paper a unified treatment is given to the problems of vibration characteristics of thin circular cylindrical shells with various end conditions with the aid of the kinematic relations of the first-order shell theory. A simple variational technique is applied to give a cubic frequency equation. This cubic is reduced to two simple linear relations for the frequency parameter by incorporating an engineering approximation relating deflections in two different ways: in general, and in the inertia components only.

79-1832

Large Amplitude Oscillations of Thick Hyperelastic Cylindrical Shells

M. Shahinpoor and R. Balakrishnan

College of Engrg., Pahlavi Univ., Shiraz, Iran, Intl. J. Nonlin. Mech., 13 (5/6), pp 295-301 (1978) 4 figs, 25 refs

Key Words: Cylindrical shells, Forced vibration, Free vibration

Numerical solutions to the problem of large amplitude oscillations of a thick-walled hyperelastic cylindrical shell employing the general theory of finite dynamic deformations of elastic bodies are presented. The material of the shell is considered incompressible and of Mooney-Rivlin type rubbers. A fourth-order Runge-Kutta numerical technique to the governing equation is applied. The free as well as forced oscillations due to a Heaviside step load are considered and graphs for the variations of amplitude against time and frequencies for different thicknesses and material constants are displayed. Discussions are presented on the significance of the results obtained.

79-1833

Non-Linear Vibrations of Cylindrical Shells of Varying Thickness in an Incompressible Fluid

J. Ramachandran

Dept. of Appl. Mechanics, Indian Inst. of Tech., Madras 600036, India, J. Sound Vib., 64 (1), pp 97-106 (May 8, 1979) 3 figs, 8 tables, 13 refs

Key Words: Shells, Cylindrical shells, Variable cross section, Flexural vibrations, Rayleigh-Ritz method

Non-linear transverse vibrations of elastic, orthotropic cylindrical shells of linearly varying thickness and embedded in an incompressible fluid are analyzed by using the Rayleigh-Ritz procedure. Numerical results are presented for various types of boundary conditions and taper ratios.

RINGS

(See No. 1720)

STRUCTURAL

(Also see No. 1707)

79-1834

Transient Analysis of Structural Members of the CSDT Riccati Transfer Matrix Method

F.H. Chu and W.D. Pilkey

John J. McMullen Associates, Inc., One World Trade Center, Suite 3047, New York, NY 10048, Computers Struc., 10 (4), pp 599-611 (Aug 1979) 17 figs, 31 refs

Key Words: Structural members, Transfer matrix methods, Transient response

A method for the direct integration of the dynamic governing partial differential equations of motion for structural members is developed. This technique is called the continuous-space discrete-time (CSDT) Riccati transfer matrix method. This formulation transforms a boundary value problem of governing partial differential equations of motion into a boundary value problem of ordinary differential equations.

SYSTEMS

ABSORBER

(Also see Nos. 1743, 1753)

79-1835

Vibration Absorber for the Reduction of Machinery Noise (Schwingungsabsorber zur Reduzierung des Maschinenlärms)

O. Bschorr and H. Albrecht

VDI Z., 121 (6), pp 253-260 (Mar 1979) 13 figs, 1 table, 12 refs

(In German)

Key Words: Vibration absorption (equipment), Machinery noise, Noise reduction

Construction and operation of a vibration absorber is described and compared with conventional means, especially the reduction of sound by means of coatings.

79-1836

Effect of Primary System Damping on the Optimum Design of an Untuned Viscous Dynamic Vibration Absorber

V.A. Bapat and H.V. Kumaraswamy

Dept. of Mech. Engrg., Indian Inst. of Science, Bangalore 560012, India, J. Sound Vib., 63 (4), pp 469-474 (Apr 22, 1979) 4 figs, 2 refs

Key Words: Dynamic vibration absorption (equipment), Viscous damping, Single degree of freedom systems

Explicit criteria for the optimum design of an untuned viscous dynamic vibration absorber are developed for the case of a viscously damped single degree of freedom spring-mass system.

79-1837

Impact of a Linearly Elastic Rod on a Thin Linearly Viscoelastic Target

C. Matuk

Dept. of Mech. Engrg., Univ. of Lulea, S-951 87 Lulea, Sweden, J. Sound Vib., 64 (1), pp 45-55 (May 8, 1979) 7 figs, 7 refs

Key Words: Energy absorption

The impact of a linearly elastic rod on a thin linearly viscoelastic target which rests on a rigid foundation is considered. The behavior of the target is quasi-static. The special case of a cylindrical linearly elastic rod impacting on a thin Kelvin target is studied in detail and the maximum impact force, the coefficient of restitution, and the energy absorption of the target are determined. The type of results obtained is useful in the design of impact protection devices.

79-1838

The Effect of Foam Linings in Protective Hubs for Grinding Wheels (Wirkung von Schutzhaubenauskleidungen aus Hartschaumstoff)

C. Uhlig and M. Schwarz

Forschungszentrum des Werkzeugmaschinenbaus im VEB Werkzeugmaschinenkombinat, Fritz Heckert, Karl-Marx-Stadt, German Dem. Rep., Maschinenbautechnik, 28 (4), pp 152-156 (Apr 1979) 13, figs, 5 refs

(In German)

Key Words: Absorbers (materials), Energy absorption, Linings, Grinding machinery, Foams, Polyurethane resins

Energy absorbing characteristics of polyurethane foam linings in the protective hub of grinding wheels are investigated. Lining thickness is determined by taking into consideration the curved trajectory of the center of gravity of the fragment. Deformation characteristics of the lining are obtained by actual modeling of foam loading.

79-1839

Knitted Metals Damp Shock and Vibration

Des. News, 35 (10), pp 39-40, 42 (May 21, 1979) 10 figs

Key Words: Shock absorbers, Absorbers (materials)

Knitted-metal mesh materials are described which offer not only a unique ability to absorb shock and vibration but also can withstand hostile environments such as corrosive atmospheres, ultra-high and cryogenic temperatures, radioactive, dirty, oily and other extreme conditions.

NOISE REDUCTION

(Also see Nos. 1719, 1835)

79-1840

Porous Plastic Reduces Exhaust Noise

Des. News, 35 (10), pp 72-73 (May 21, 1979) 4 figs

Key Words: *Noise reduction, Pneumatic isolators, Exhaust noise*

A new line of pneumatic silencers uses a porous plastic element to reduce air-blast noises. The silencer action, provided by the controlled porosity of a cylindrical porous polyethylene element, is highly effective in reducing noise generated by the exhaust of air from valves.

79-1841

Water Noise in Large Cooling Tower Installations

A.M. Kunesch

Film Cooling Towers (1925), Ltd., Noise Control Vib. Isolation, 10 (4), pp 134-137 (Apr 1979) 3 figs

Key Words: Cooling towers, Noise generation, Noise prediction, Noise reduction

Noise generation, its prediction, and the application of theory to the actual noise reduction of cooling towers is discussed.

ACTIVE ISOLATION

79-1842

Active Controls for Civil Transports

H. Hitch

Commercial Aircraft Div., British Aircraft Corp., Weybridge, UK, In: AGARD Active Controls in Aircraft Design, Nov 1978, 12 pp

N79-16873

Key Words: Transportation systems, Flutter, Active control

The principles involved in Active Control Technology (ACT) for civil transports are described and estimates are made of the probable benefits. The ACT functions, maneuver load alleviation, gust load alleviation, relaxed stability, flutter suppression, ride quality improvement, and fatigue improvement are discussed in turn and the problems and benefits outlined.

79-1843

An Analytical Technique for Predicting the Characteristics of a Flexible Wing Equipped with an Active Flutter-Suppression System and Comparison with Wind-Tunnel Data

I. Abel

NASA Langley Research Ctr., Hampton, VA, Rept. No. NASA-TP-1367; L-12567, 45 pp (Feb 1979)

N79-17264

Key Words: Flutter, Active control, Aircraft wings

An analytical technique for predicting the performance of an active flutter-suppression system is presented. This technique is based on the use of an interpolating function to approximate the unsteady aerodynamics. The resulting equations are formulated in terms of linear, ordinary differential equations with constant coefficients. This technique is then applied to an aeroelastic model wing equipped with an active flutter-suppression system. Comparisons between wind-tunnel data and analysis are presented for the wing both with and without active flutter suppression.

AIRCRAFT

(Also see Nos. 1708, 1716, 1717, 1726, 1735, 1843)

79-1844

Optimization of Wing Structures to Satisfy Strength and Frequency Requirements

V.R. Rao, N.G.R. Iyengar, and S.S. Rao

Indian Inst. of Tech. P.O. I.I.T., Kanpur-208 016, India, Computers Struc., 10 (4), pp 669-674 (Aug 1979) 6 figs, 13 refs

Key Words: Aircraft wings, Minimum weight design

In this investigation minimum weight design of wing structures with restrictions on strength, stability and frequency characteristics is attempted. The multiweb delta wing structure is idealized with three different kinds of finite elements. The constant stress triangular plate elements, the rectangular shear panels and pin jointed bar elements are used to represent, respectively, the cover skins, webs and the stringers of wing structures. A parametric study is made to reduce the

number of design variables which in turn reduces the required computational effort. The feasibility of employing linearly approximated redesigns is investigated. Numerical results are presented to illustrate the feasibility. Off-design charts have been obtained by performing sensitivity analysis about the final optimum design point.

79-1845

Traffic Background Level and Signal Duration Effects on Aircraft Noise Judgment

G.W. Johnston and A.A. Haasz

Institute for Aerospace Studies, Univ. of Toronto, Downsview, Ontario, Canada M3H 5T6, J. Sound Vib., 63 (4), pp 543-560 (Apr 22, 1979) 10 figs, 8 tables, 13 refs

Key Words: Aircraft noise, Noise measurement

The effects of traffic background noise on the judged noisiness of aircraft flyover events are examined. A series of 72 flyover events are assessed by a jury of 35 observers, during 12 separate listening sessions conducted in a controlled test area designed to simulate typical indoor listening conditions. Each aircraft signal is superimposed on a controlled random traffic background signal having a duration exceeding that of the aircraft event.

79-1846

Interior Noise of STOL Aircraft and Helicopters

J.F. Wilby and J.I. Smullin

Bolt Beranek and Newman, Inc., P.O. Box 633, 21120 Vanowen St., Canoga Park, CA 91305, Noise Control Engr., 12 (3), pp 100-110 (May/June 1979) 16 figs, 38 refs

Key Words: Aircraft, Helicopters, Interior noise, Noise reduction

Sound levels in STOL aircraft and helicopters can be significantly higher than those in other airborne and surface vehicles. The sound fields are dominated by discrete frequency components associated with rotating machinery, except for STOL aircraft with powered lift devices. A review of available noise control techniques indicates that current methods are inadequate at low frequencies, which are important in STOL aircraft and helicopters.

79-1847

Aircraft Windshield Bird Impact Math Model. Part 3. Programming Manual

R.C. Morris

Douglas Aircraft Co., Long Beach, CA, Rept. No. MDC-J-7174-PT-3, AFFDL-TR-77-99-PT-3, 494 pp (Dec 1977)

AD-A063 741/3GA

Key Words: Aircraft, Windows, Impact response (mechanical)

This report describes the Bird Impact Math Model (IMPACT), a computer program designed especially for the purpose of calculating transient dynamic responses of aircraft windshield and canopy systems, composed of laminated transparencies and supporting structures, to bird impact. Part 3 describes the design, operation, and implementation of the computer program code. Each of the seven programs comprising IMPACT are described individually in terms of coding strategy, internal and external storage utilization, limitations, error detection, and interaces between programs. Detailed descriptions of each subroutine are also included.

79-1848

A Study of the Effects of Aircraft Dynamic Characteristics on Structural Loads Criteria

R.L. Stapleford and R.J. DiMarco

Systems Technology, Inc., Hawthorne, CA, Rept. No. Contract DOT-FA77WA-3936; STI-TR-1099-1; FAA-RD-78-155, 245 pp (Nov 1978)

N79-16838

Key Words: Crash research (aircraft), Wind-induced excitation

An analysis of in-flight airframe failure accidents which occurred during a ten-year period, 1966-1975 is included. A number of potentially contributing factors, including stability and control characteristics and handling qualities, are examined and correlated with the accident data. The study also covers a review of proposed criteria for continuous gusts and a comparison with existing discrete gust criteria. Problems in the selection of a turbulence penetration speed are also examined.

79-1849

Tests of Crash-Resistant Fuel System for General Aviation Aircraft

W.M. Perrella, Jr.
National Aviation Facilities Experimental Center, Atlantic City, NJ, Rept. No. FAA Proj. 184-521-100, FAA-RD-78-122; FAA-NA-78-48, 38 pp (Dec 1978)
N79-16815

Key Words: Crash research (aircraft), Fuel tanks, Fuel flammability

Tests were conducted to demonstrate the performance of light-weight, flexible, crash-resistant fuel cells combined with the use of frangible fuel line couplings. Four full-scale crash tests of a typical light twin aircraft were included in these tests.

BRIDGES

(See No. 1776)

BUILDING

79-1850

Experimental Study of the Dynamic Response of a Ten-Story Reinforced Concrete Frame with a Tall First Story

T.J. Healey
Dept. of Civil Engrg., Illinois Univ. at Urbana-Champaign, Urbana, IL, Rept. No. PB-287986/4; STRUCTURAL-RESEARCH-SER-450; UILU-ENG-78-2012, 128 pp (Aug 1978)
N79-17062

Key Words: Buildings, Multistory buildings, Reinforced concrete, Seismic response, Earthquake response, Simulation

The experimental work and the response data obtained in three earthquake simulation tests of a ten-story reinforced concrete frame are presented. Changes in the dynamic properties of the test structure, such as apparent frequencies and equivalent damping, are discussed. Observed maximum lateral displacements are compared with those obtained from modal spectral analysis.

79-1851

Effects of Batken-Isfara Earthquake January 31, 1977

L.S. Kilimnik and A.M. Zharov
Earthquake Resistance Dept., TsNIISK named after Kucherenko Gosstroy of the USSR, Moscow, Symp. Earthquake Engrg., Oct 5-7, 1978, Univ. of Roorkee, Roorkee, India, pp 577-581, 7 figs, 1 ref

Key Words: Buildings, Earthquake damage

The paper deals with the results of post earthquake analysis of Batken-Isfara earthquake of January 31, 1977 in Kirgiz SSR and Tajik SSR where seismic intensities were 6-8 degrees. The data on typical damage of buildings with various structural solutions are presented as well as quantitative estimates of ground vibrations parameters and recommendations for seismic scale improvement.

79-1852

Design Problems of Expansed Frame Buildings

M.A. Mardzanishivili
Large-Panel Structure Building Lab., TbilZNIIEP, Tbilissi, USSR, Symp. Earthquake Engrg., Oct 5-7, 1978, Univ. of Roorkee, Roorkee, India, pp 569-572, 2 figs, 1 ref

Key Words: Buildings, Earthquake damage, Seismic design

The author suggests that in seismic design of buildings the structure should be considered as a two-layered continuous beam on a Winkler foundation, instead of a cantilever beam. This allows the consideration of the kinematic shifts and prevention of the formation of cracks in the vertical plane of the upper part of the building.

79-1853

Analysis of Reinforced Concrete Frame-Wall Structures for Strong Motion Earthquakes

K. Emori and W.C. Schnobrich
Dept. of Civil Engrg., Illinois Univ. at Urbana-Champaign, IL, Rept, No. UILU-ENG-78-2025, STRUCTURAL-RESEARCH-SER-457, 206 pp (Dec 1978)
PB-291 995/9GA

Key Words: Multistory buildings, Beams, Cantilever beams, Earthquake response, Reinforced concrete

The nonlinear response and failure mechanism of reinforced concrete frame-wall systems are investigated through mechanical models for both dynamic loads and static loads. Three mechanical models: a concentrated spring model, a multiple spring model, and a layered model, which take into account inelastic behavior of a reinforced concrete cantilever beam, are presented. Ten story reinforced concrete frame-wall structures are investigated. The stiffness characteristics of each constituent member are determined through one of the mechanical models by its inelastic properties or by a hysteresis model. The procedure of a load increment analysis is used for a static loading case. The equations of motion are solved by a step by step integration procedure for a dynamic loading case. Computed results are compared with experimental results.

79-1854

A New Building System for Improved Earthquake Performance

A.S. Arya, B. Chandra, and M. Qamaruddin
Dept. of Earthquake Engrg., Univ. of Roorkee, U.P., India, Symp. Earthquake Engrg., Oct 5-7, 1978, Univ. of Roorkee, Roorkee, India, pp 499-504, 5 figs, 7 refs

Key Words: Buildings, Seismic design, Coulomb friction, Sliding friction

A new system of single-story brick buildings has been analyzed in which the structure is partly isolated and the seismic energy is partly made to dissipate through friction. In the proposed system, the superstructure is made free to slide over the foundation masonry at plinth level. The mathematical model of the structure consists of two lumped masses, one at the roof and the other at plinth levels.

79-1855

Identification of Elastic and Damping Coefficients in a Multistorey Building by Cross-Correlation Analysis

F. Buckens
U.C.L., 1348, Louvain-la-Meuve, Belgium, Symp. Earthquake Engrg., Oct 5-7, 1978, Univ. of Roorkee, Roorkee, India, pp 511-515, 4 refs

Key Words: Buildings, Multistory buildings, Beams, Parameter identification technique, Vibrating structures, Damping coefficients, Cross correlation technique

The problem of identifying physical parameters in a vibrating structure can be solved by measurements based on stochastic methods. This is considered for buildings in which a coupling exists due to non-diagonal damping between the different modes. It is done in the case of a high-rise building which can be modeled by a beam.

79-1856

Seismic Loads and Structural Safety with Particular Reference to Northeastern Region of India

A.C. Khazanchi and T.K. Dutta
Regional Research Lab., Jorhat, Assam, India, Symp. Earthquake Engrg., Oct 5-7, 1978, Univ. of Roorkee, Roorkee, India, pp 523-528, 7 figs, 1 table, 15 refs

Key Words: Buildings, Seismic design

The present paper attempts a general discussion on estimating seismic loads necessary for structural safety in construction in seismic zones in relation to provisions adopted in the I.S. code for the Northeastern region of India.

79-1857

An Earthquake Response Parameter for Spectral Mode Superposition of Buildings

M.G. Joseph and R. Radhakrishnan
Central Public Works Dept., Room No. 203, A-Wing, Nirman Bhawan, New Delhi, Symp. Earthquake Engrg., Oct 5-7, 1978, Univ. of Roorkee, Roorkee, India, pp 529-534, 6 figs, 4 refs

Key Words: Buildings, Multistory buildings, Earthquake response, Modal superposition method

The paper presents an analytical case study made on the relative efficacy of the mode superposition methods commonly used for determining earthquake response of multistory buildings from response spectra. A parameter to account for the pattern of earthquake in the spectral mode superposition is also evolved and recommended on the basis of the study.

79-1858

Seismic Analysis of Unsymmetrical Buildings

V.N. Gupchup, S. Sundaram, and C.G. Samant

Structural Engrg. Dept., Victoria Jubilee Technical Inst., Bombay - 400 019, Symp. Earthquake Engrg., Oct 5-7, 1978, Univ. of Roorkee, Roorkee, India, pp 543-547, 5 figs, 5 refs

Key Words: Buildings, Multistory buildings, Seismic response spectra, Ground motion, Computer programs

In this paper a general procedure of seismic analysis of multistory buildings is presented. For earthquake ground motion in any direction three degrees of freedom per floor is considered. This includes horizontal translation in two perpendicular directions and rotation about a vertical axis through the center of mass of each floor. A comprehensive computer program is developed for the analysis using the response spectrum technique.

79-1859

Rational Types of Aseismic Designs for Tall Buildings

N.D. Tuichiyev

Uzbek Town - Building Research and Designing Inst., Tashkent, USSR, Symp. Earthquake Engrg., Oct 5-7, 1978, Univ. of Roorkee, Roorkee, India, pp 557-560, 3 figs

Key Words: Buildings, Multistory buildings, Seismic design

This paper substantiates the importance of selecting rational alternatives for the aseismic designs of tall apartment houses and public buildings. The task of achieving an overall optimum design can be solved in two stages: in the first stage a comparative study of alternatives makes it possible to select the most rational design; in the second stage the task of optimization is solved for the selected alternative.

79-1860

Experimental Studies of the Frame Joints

V.N. Shaishmelashvili, M.A. Bediashvili, and R.K. Gabuzov

TbilZNIIEP, Tbilissi, USSR, Symp. Earthquake Engrg., Oct 5-7, 1978, Univ. of Roorkee, Roorkee, India, pp 573-575, 3 figs, 2 refs

Key Words: Buildings, Seismic design, Joints (junctions)

The paper deals with the test results of the natural samples of the frame joints which manifest the reinforcement of the central part of the joint by the diagonal rods and provide the necessary strength at the combined action of the vertical load on the column and slanting-symmetrical moments on the collar beams.

79-1861

Industrialization of Earthquake Proof Construction of Stone Buildings

C.C. Grafov and Y.V. Izmailov

State Construction Committee, Council of Ministers of the Moldavian SSR, USSR, Symp. Earthquake Engrg., Oct 5-7, 1978, Univ. of Roorkee, Roorkee, India, pp 561-564, 2 figs

Key Words: Buildings, Stone buildings, Seismic design

The paper presents a view that natural stone may be used to advantage over other types of building systems in the industrial construction of earthquake resistant buildings.

79-1862

On Determining Stresses in Walls of the Frame-Stone Buildings

A.A. Chuprina

Kishinev Antiseismic Lab., Central Scientific Res. Inst. for Building Structures, USSR, Symp. Earthquake Engrg., Oct 5-7, 1978, Univ. of Roorkee, Roorkee, India, pp 565-567, 4 figs

Key Words: Buildings, Stone buildings, Seismic design

The determination of vertical load stresses in the seismic design of frame-stone building walls is described. First, the longitudinal stresses in the frame posts are determined. Then the bending moments and lateral forces in the gantry beams and stresses in the masonry under the gantry beams are obtained.

79-1863

A Response Spectrum for Dynamic Effects of Wind on Tall Structures

M.G. Joseph and R. Radhakrishnan

Central Public Works Dept., Room No. 203, A-Wing, Nirman Bhawan, New Delhi, India, Symp. Earthquake Engrg., Oct 5-7, 1978, Univ. of Roorkee, Roorkee, India, pp 495-498, 2 figs, 2 refs

Key Words: Buildings, Towers, Wind-induced excitation, Response spectra

The paper approaches the dynamic response of buildings and towers due to in-line gust excitations in the direction of wind by a response spectrum technique.

79-1864

A Rigorous Elastic Response Analysis of Tall Structures Subjected to Dynamic Wind Loads

M.G. Joseph and R. Radhakrishnan

Central Public Works Dept., Room No. 203, A-Wing, Nirman Bhawan, New Delhi, India, Symp. Earthquake Engrg., Oct 5-7, 1978, Univ. of Roorkee, Roorkee, India, pp 517-522, 3 figs, 1 table

Key Words: Towers, Buildings, Wind-induced excitation

The paper presents a rigorous method for elastic response analysis of tall buildings and towerlike structures subjected to dynamic wind loading. The method is applicable to forced vibration in buildings: the in-line gust excitation in the direction of the wind.

FOUNDATIONS AND EARTH

(See No. 1772)

HELICOPTERS

79-1865

Engine/Airframe/Drive Train Dynamic Interface Documentation

H.W. Hanson, R.W. Balke, B.D. Edwards, W.W. Riley, and B.D. Downs

Bell Helicopter Textron, Fort Worth, TX, Rept. No. USARTL-TR-78-15, 204 pp (Oct 1978)
AD-A063 237/2GA

Key Words: Helicopters, Helicopter engines, Dynamic structural analysis

The purpose of this program was to survey Bell Helicopter Textron past and present experiences as related to gas-turbine-powered helicopter engine/airframe/drive train dynamic interface problems as part of an overall Government effort to define specific areas in which future research funding should be placed to develop improved design, analytical and test methods to ensure helicopter dynamic compatibility. Thirteen dynamic interface problems have been documented with a detailed discussion, solutions considered and/or applied, and identifiable shortcomings. Recommendations are made for future research funding in five specific areas. The appendixes provide the detailed documentation for each of the dynamic interface problems.

ISOLATION

79-1866

Double-Pendulum Vibration Isolator with Three-Dimensional Isolation

P. Lorrain

Dept. de physique, Universite de Montreal, Canada, H3C 3J7, Rev. Scientific Instr., 50 (5), pp 664-666 (May 1979) 1 fig, 2 refs

Key Words: Vibration isolators

This isolator consists of a platform suspended by three springs, the damping being provided by a much smaller mass, suspended from the platform by a spring and damped in an oil bath. This simple device is a highly effective isolator, with a weak resonance peak and a transmissibility that decreases both horizontally and vertically.

79-1867

Torsion Spring/Pin Suspension is (Nearly) Perfect Motor Mount

Des. News, 35 (10), pp 67-69 (May 21, 1979) 5 figs

Key Words: Mounts, Motors, Torsion bars

The motor of a new cartridge tape drive is suspended on a torsion spring arrangement, such that the suspension axis passes through the center of gravity of the mount assembly. A rotation axis passing through the cg is formed by a pin on one side, and a torsion spring on the other. The torsion spring is biased to ensure the normal force between the drive capstan and cartridge.

MATERIAL HANDLING

79-1868

Dynamic Analysis of Steering Forces in Belt Conveyors

N. Basavanhally, J.F. Chmielewski, and G. Saliba
Univ. of Pittsburgh, Pittsburgh, PA, ASME Paper No. 78-WA/MH-3

Key Words: Conveyors, Belt conveyors, Mathematical models

This paper presents an analysis of the mechanics of conveyor belt training and identifies the significant parameters which govern transverse tracking forces in belt conveyors. Cases considered in the analysis are for no circumferential belt slip and also for the condition where bidirectional slip may occur. Experimental results on a full-sized conveyor belt system are compared with the mathematical model.

MECHANICAL

79-1869

Experimental Investigation of the Drive System of a Slewing Crane Truck (Experimentelle Untersuchungen am Fahrantrieb eines Autodrehkrans)

A. Lingener, G. Kunad, and J. Bätge
Technische Hochschule "Otto von Guericke" Magdeburg, German Dem. Rep., Maschinenbautechnik, 28 (4), pp 166-168 (Apr 1979) 6 figs, 2 refs
(In German)

Key Words: Trucks, Drive line vibrations, Experimental data

In a test vehicle of the slewing crane truck series, harmful vibrations of the drive system were observed. To find the reason for the increase in these vibrations, speed-related inertia moments, spring characteristics, transmitted torques, and torsional vibrations are measured.

79-1870

Theoretical Evaluation of the Dynamic Behavior of the Drive System of a Slewing Crane Truck (Theoretische Abschätzung des dynamischen Verhaltens des Fahrantriebs eines Autodrehkrans)

A. Lingener, G. Kunad, and D. Spielhagen
VEB Technische Hochschule "Otto von Guericke" Magdeburg, German Dem. Rep., Maschinenbautechnik, 28 (4), pp 169-172 (Apr 1979) 4 figs, 1 table, 5 refs
(In German)

Key Words: Trucks, Drive line vibrations, Mathematical models

Using the results obtained on a test vehicle, several mathematical models of a drive system with drive shafts are investigated. Equations of motion for the torsional vibration of an elastic model are set up. Their solution on an analog computer provides a theoretical basis for the experimentally measured vibrations and a means for implementing required changes in the design of the drive system.

METAL WORKING AND FORMING

(See Nos. 1743, 1838)

OFF-ROAD VEHICLES

(See No. 1724)

OPTICAL

(Also see No. 1748)

79-1871

Glass Curtain Wall Elements: Properties and Behavior

B.J. Goodno
School of Civil Engrg., Georgia Inst. of Tech., Atlanta, GA, ASCE J. Struc. Div., 105 (ST6), pp 1121-1136 (June 1979) 7 figs, 5 tables, 39 refs

Key Words: Plates, Walls, Windows, Multistory buildings, Finite element technique, Vibration response

A frame-panel finite element model is developed to represent a typical portion of the glass curtain wall between story levels in a 29-story glass-clad building and a parametric study of its displacement response and vibration properties is conducted. Vibration frequencies of the frame-window system are in good agreement with values obtained in field and laboratory experiments.

PUMPS, TURBINES, FANS, COMPRESSORS

(See Nos. 1777, 1799)

RAIL

79-1872

Coupled Lateral-Vertical Dynamics of Rubber-Tired Automated Guideway Transit Vehicles with Random Guideway Inputs

Y.K. Kwak and C.C. Smith

Korea Military Academy, Seoul, Korea, ASME Paper No. 78-WA/DSC-30

Key Words: Interaction: vehicle-guideway, Vibration response, Simulation

A method is presented which permits the simulation of the coupled lateral-vertical rigid body vibration response of a rubber-tired automated guideway transit (AGT) vehicle subject to guideway random irregularities. A coupled lateral-vertical dynamic model is developed. The general motions are expressed by Euler angles and inertial displacements. Basic vehicle dynamic modes are determined. A predicted lateral acceleration spectrum of the linearized model using guideway surface profile models for inputs are compared with the measured lateral acceleration spectra.

79-1873

Establishment of Dampening Required for Control of Railroad Truck Hunting

S. Guins

Transportation Consultant, Pueblo, CO, ASME Paper No. 78-WA/RT-17

Key Words: Railroad cars, Hunting motion, Interaction: rail-wheel, Critical damping

This paper offers a means to calculate the critical dampening that can control hunting, disregarding the geometry of wheel tread profiles. The equations for frequency and dampening required for control of the motion are based on the elasticity of the system at the area of contact between wheel and rail, and the castering characteristics of the railroad vehicle truck.

79-1874

Some Static and Dynamic Properties of Railway Wheels

L. Strasberg, N. Perfect, and G.L. Elliott

Ontario Ministry of Transportation and Communications, Downsview, Ontario, Canada, ASME Paper No. 78-WA/RT-4

Key Words: Railway wheels, Interaction: rail-wheel, Noise generation, Natural frequencies, Modal damping, Mode shapes

Experiments were conducted on four railway wheels to determine their static and dynamic behavior. The railway wheels used were the Bochum wheel, the Acoustaflex wheel, the S.A.B. wheel and a standard railway wheel. The properties measured were their frequencies, modal damping ratios, and mode shapes. Deflection properties are also given.

79-1875

Freight Car Truck Design Optimization. Volume VIII. Results Report for Test Series 2 and 5

Technical Res. and Dev. Group, Southern Pacific Transportation Co., San Francisco, CA, Rept. No. TDOP-76-27, FRA/ORD-78/12.VIII, 232 pp (May 1978)

PB-290 663/4GA

Key Words: Railroad cars, Freight cars, Interaction: rail-wheel

This report contains information on the Truck Design Optimization Project (TDOP) data tapes. These results encompass data from Test Series 2 and data from the 70-ton mechanical refrigerator car used in Test Series 5. Test Series 5 also includes data from a 100-ton boxcar on cylindrical profile wheels with spring variations and snubbing supplements.

79-1876

Effect of Torsional Fastener Resistance on the Lateral Response of a Rail-Tie Structure

A.D. Kerr

Dept. of Civil Engrg., Princeton Univ., NJ, Rept. No. 77-TR-8, FRA/ORD-78/35, 28 pp (Sept 1978)

PB-290 734/3GA

Key Words: Railroad tracks, Beams, Lateral response, Torsional strength

The purpose of the present study is to establish the effect of fastener resistance on the lateral response of the rail-tie structure and also to determine whether a fourth order differential equation, which includes a rotational resistance term, is sufficiently accurate for describing its lateral response. Deflection tests were conducted on a rail-tie structure with adjustable fastener rigidities, then this test-structure was analyzed using a fourth order equation with and without a rotational resistance term, and subsequently the analytical and tests results were compared.

79-1877

Empirical Load-Response Analysis of a Railroad Tank Car

J.D. Parsons and S.A. Wieneke

Union Tank Car Co., East Chicago, IN, ASME Ppaer No. 78-WA/RT-2

Key Words: Railroad cars, Tank cars, Dynamic response

Union Tank Car Co. has attempted, through acquisition and analysis of road test data, to better understand cause and effect relationships of loads and their responses on stability and life of tank cars. Accomplishment of this objective involved design and construction of a new acquisition car and collection of over 4000 mi (6400 km) of road test data for an instrumented tank car.

79-1878

The Effect of Spring Stiffness, Friction Damping Level, and Car Body Stiffness Upon the Ride Quality of Railroad Freight Cars

L.P. Greenfield, E.J. Wolf, and M.F. Hengel

Trailer Train Co., Chicago, IL, ASME Paper No. 78-WA/RT-8

Key Words: Railroad cars, Freight cars, Ride dynamics, Spring constants, Coulomb friction

An over-the-road test was performed for the purpose of determining the effect of various levels of spring stiffness and friction damping upon the ride quality of three different types of railroad cars. Instrumentation consisted of spring deflection transducers, vertical and lateral accelerometers and strain gages. Data is presented in the format of plots of acceleration versus speed with supporting plots of spring displacement and roll angles.

REACTORS

(Also see No. 1827)

79-1879

Protective Structure Response to Vehicle Impact

J.J. Labra

Southwest Research Inst., San Antonio, TX, ASCE J. Struc. Div., 105 (ST6), pp 991-1005 (June 1979) 17 figs, 2 tables, 16 refs

Key Words: Protective shelters, Reinforced concrete, Nuclear reactors, Impact tests, Finite element technique, Computer programs

Sustainability of protective structures to dynamic impact is investigated using computer finite element modeling. As a means of validating the concrete panel model, a simulation was performed of a steel pipe impact with the concrete panel. Results are compared with actual experimental testing.

ROAD

79-1880

Baseline Test of Compact Vehicle Side Structure, 25-35 mph, 60-90 Degree Impact, Torino-to-Volare, Test Nos. 1, 3, 4, 6-9, 11

E. Enserink

Dynamic Science, Phoenix, AZ, Rept. No. DOT-HS-803, 779, 781, 782, 784, 785-787, 789 (Jan 1979) PB-292 057/7GA, 058/5GA, 059/3GA, 060/1GA, 061/9GA, 062/7GA, 063/5GA, 064/3GA

Key Words: Collision research (automotive), Crashworthiness, Experimental data

These tests were run to investigate and improve crashworthiness of compact sized vehicle side structures. They were run at 25-35 mph striking angle of 60-90 degrees. A 1975 Ford Torino was the bullet vehicle and a standard 1976 Plymouth Volare the target vehicle.

ROTORS

(Also see Nos. 1752, 1798)

79-1881

Estimation of the Distributing Cross Sectional Asymmetry Along the Rotor Axis

Y. Matsukura, T. Inoue, M. Kiso, M. Tomisawa, and N. Oishi
Central Research Lab., Mitsubishi Electric Corp., Amagasaki, Japan, Bull. JSME, 22 (166), pp 491-496 (Apr 1979) 8 figs, 5 tables, 6 refs

Key Words: Rotors, Shafts, Asymmetry

A method is presented for estimating the asymmetry of flexural rigidity which varies along a rotor axis. A pair of natural frequencies on two principal planes are measured. Such experimental results are combined with numerical ones for estimating asymmetry. The procedure is discussed in detail. The amount of asymmetry on an actual turbogenerator is also estimated.

SELF-EXCITED

79-1882

New Type of Self-Excited Oscillator

M. Lambeck
Fachbereich Physik, Sekr. P11, Technische Universität, D 1000 Berlin 12, Federal Rep. of Germany, Rev. Scientific Instr., 50 (5), pp 619-621 (May 1979) 4 figs, 2 refs

Key Words: Self-excited vibrations, Oscillators, Circuit boards

Applications for contactless measurement of the conductivity, permeability, diameter, and thickness of materials, and displacement measurements are discussed.

79-1883

Gate Edge Suction as a Cause of Self-Exciting Vertical Vibrations

P.A. Kolkman and A. Vrijer
Delft Hydraulics Lab., The Netherlands, Rept. No. Publ-188, 10 pp (Nov 1977)
N79-19310

Key Words: Hydraulic systems, Self-excited vibration

A theory of self-exciting vertical vibrations is presented.

SPACECRAFT

79-1884

Skylab Viscous Damper Study

Space Div., General Electric Co., Philadelphia, PA, Rept. No. NASA Order H-34352-B; NASA-CR-150845, 19 pp (Nov 1978)
N79-11093

Key Words: Viscous damping, Space shuttles, Spacecraft

The proposed magnetically anchored viscous fluid damper can maintain the Skylab in a gravity-gradient stabilized mode at the anticipated reboost altitudes. The parameters influencing damper performance (and thereby affecting the degree of risk) are: amount of skylab pitch bias in the orbit plane which will result from aerodynamic trim conditions of the post-reboost configuration Skylab; the lowest altitude to which the post-reboost Skylab will be allowed to decay prior to the next rendezvous; maximum allowable weight and size of the proposed damper in order to match shuttle/TRS mission constraints; and the amount of magnetic materials expected to be in the vicinity of the damper.

TRANSMISSIONS

(Also see Nos. 1869, 1870)

79-1885

Centrifugal Clutch Basics

R.C. St. John
Mercury Clutch Div., ASPRO, Inc., Canton, OH, Power Transm. Des., 21 (3), pp 52-55 (Mar 1979) 7 figs, 2 tables

Key Words: Clutches

Starting and stopping loads on equipment are relieved by using properly selected clutches. Centrifugal clutches help relieve stresses by automatically limiting the torque transmitted between drive and load.

79-1886
Calculating V-Belt Torque Capacity
L.R. Oliver, W.F. Breig, and D.D. Hall
Dayco Corp., Springfield, MO, Power Transm. Des., 20 (4), pp 39-41 (Apr 1978) 4 figs

Key Words: Power transmission belts, V-belts, Torque, Graphic methods

V-belt drives are designed to transmit peak and intermittent loads that are much higher than manufacturers' ratings. Charts for determining limits for short-term overloading and peak torque capability of industrial V-belts are provided.

TURBOMACHINERY

79-1887
Characteristics of Aeroelastic Instabilities in Turbomachinery - NASA Full Scale Engine Test Results
J.F. Lubomski
NASA Lewis Research Ctr., Cleveland, OH, Rept. No. NASA-TM-79085, E-9908, 21 pp (1979)
N79-17263

Key Words: Turbomachinery, Flutter

Several aeromechanical programs were conducted in the NASA/USAF Joint Engine System Research Programs. The scope of these programs, the instrumentation, data acquisition and reduction, and the test results are discussed. Data pertinent to four different instabilities were acquired: two types of stall flutter, choke flutter and a system mode instability.

AUTHOR INDEX

CALENDAR

OCTOBER 1979

7-11 **Fall Meeting and Workshops,** [SESA] Mason, OH ***(SESA, 21 Bridge Square, P.O. Box 277, Saugatuck Sta., Westport, CT 06880 - Tel (203) 227-0829)***

16-18 **50th Shock and Vibration Symposium,** Colorado Springs, CO ***(H.C. Pusey, Director, The Shock and Vibration Information Center, Code 8404, Naval Research Lab., Washington, D.C. 20375 - Tel (202) 767-3306)***

16-18 **Joint Lubrication Conference,** [ASLE-ASME] Dayton, OH ***(ASME Hq.)***

17-19 **Stapp Car Crash Conference** [SAE] Hotel del Coronado, San Diego, CA ***(SAE Meeting Dept.)***

NOVEMBER 1979

4-6 **Diesel and Gas Engine Power Technical Conference,** San Antonio, TX ***(ASME Hq.)***

5-8 *Truck Meeting,* [SAE] *Marriott, Ft. Wayne, IN* ***(SAE Meeting Dept.)***

26-30 **Acoustical Society of America, Fall Meeting,** [ASA] Salt Lake City, UT ***(ASA Hq.)***

27-29 **8th Turbomachinery Symposium,** [Gas Turbine Labs., Texas A&M University] Houston, TX ***(Dr. M.P. Boyce, Gas Turbine Labs., Dept. of Mech. Engrg., Texas A&M University, College Station, TX 77843 - Tel (713)845-7417)***

DECEMBER 1979

Aerospace Meeting [SAE] Los Angeles, CA ***(SAE Meeting Dept.)***

2-7 **Winter Annual Meeting** [ASME] Statler Hilton, New York, NY ***(ASME Hq.)***

FEBRUARY 1980

26-29 **Congress & Exposition** [SAE] Cobo Hall, Detroit, MI ***(SAE Meeting Dept.)***

MARCH 1980

9-13 **25th Annual International Gas Turbine Conference and Exhibit** [ASME] New Orleans, LA ***(ASME Hq.)***

APRIL 1980

21-25 **Acoustical Society of America, Spring Meeting** [ASA] Atlanta, GA ***(ASA Hq.)***

MAY 1980

25-30 **Fourth SESA International Congress on Experimental Mechanics,** [SESA] The Copley Plaza, Boston, MA ***(SESA Hq.)***

JULY 1980

7-11 **Recent Advances in Structural Dynamics Symp.,** [Institute of Sound and Vibration Research] University of Southampton, Southampton, SO9 5NH, UK ***(Mrs. O.G. Hyde, ISVR Conference Secretary, The University, Southampton, SO9 5NH, UK - Tel (0703) 559122, Ext 2310)***

OCTOBER 1980

6-8 **Computational Methods in Nonlinear Structural and Solid Mechanics,** [George Washington University & NASA Langley Research Center] Washington, D.C. ***(Professor A.K. Noor, The George Washington University, NASA Langley Research Center, MS246, Hampton, VA 23665- Tel (804) 827-2897)***

NOVEMBER 1980

18-21 **Acoustical Society of America, Fall Meeting** [ASA] Los Angeles, CA ***(ASA Hq.)***

CALENDAR ACRONYM DEFINITIONS AND ADDRESSES OF SOCIETY HEADQUARTERS

AFIPS: American Federation of Information Processing Societies
210 Summit Ave., Montvale, NJ 07645

AGMA: American Gear Manufacturers Association
1330 Mass. Ave., N.W.
Washington, D.C.

AHS: American Helicopter Society
1325 18 St. N.W.
Washington, D.C. 20036

AIAA: American Institute of Aeronautics and Astronautics, 1290 Sixth Ave.
New York, NY 10019

AIChE: American Institute of Chemical Engineers
345 E. 47th St.
New York, NY 10017

AREA: American Railway Engineering Association
59 E. Van Buren St.
Chicago, IL 60605

AHS: American Helicopter Society
30 E. 42nd St.
New York, NY 10017

ARPA: Advanced Research Projects Agency

ASA: Acoustical Society of America
335 E. 45th St.
New York, NY 10017

ASCE: American Society of Civil Engineers
345 E. 45th St.
New York, NY 10017

ASME: American Society of Mechanical Engineers
345 E. 45th St.
New York, NY 10017

ASNT: American Society for Nondestructive Testing
914 Chicago Ave.
Evanston, IL 60202

ASQC: American Society for Quality Control
161 W. Wisconsin Ave.
Milwaukee, WI 53203

ASTM: American Society for Testing and Materials
1916 Race St.
Philadelphia, PA 19103

CCCAM: Chairman, c/o Dept. ME, Univ. Toronto, Toronto 5, Ontario, Canada

ICF: International Congress on Fracture
Tohoku Univ.
Sendai, Japan

IEEE: Institute of Electrical and Electronics Engineers
345 E. 47th St.
New York, NY 10017

IES: Institute of Environmental Sciences
940 E. Northwest Highway
Mt. Prospect, IL 60056

IFToMM: International Federation for Theory of Machines and Mechanisms, U.S. Council for TMM, c/o Univ. Mass., Dept. ME
Amherst, MA 01002

INCE: Institute of Noise Control Engineering
P.O. Box 3206, Arlington Branch
Poughkeepsie, NY 12603

ISA: Instrument Society of America
400 Stanwix St.
Pittsburgh, PA 15222

ONR: Office of Naval Research
Code 40084, Dept. Navy
Arlington, VA 22217

SAE: Society of Automotive Engineers
400 Commonwealth Drive
Warrendale, PA 15096

SEE: Society of Environmental Engineers
6 Conduit St.
London W1R 9TG, UK

SESA: Society for Experimental Stress Analysis
21 Bridge Sq.
Westport, CT 06880

SNAME: Society of Naval Architects and Marine Engineers, 74 Trinity Pl.
New York, NY 10006

SPE: Society of Petroleum Engineers
6200 N. Central Expressway
Dallas, TX 75206

SVIC: Shock and Vibration Information Center
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Washington, D.C. 20375

URSI-USNC: International Union of Radio Science - US National Committee c/o MIT Lincoln Lab., Lexington, MA 02173

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